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TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

THE FUTURE OF THE ELECTRIC FURNACE.

By C. T. BRAGG.

Read at the Boston Meeting, June 18, 1919.

"A prophet is not without honor, save in his own country." Also it is perfectly true that he is often honorless everywhere else. However, it is perfectly safe to make predictions relative to the electric furnace. Its future is to be better than its past and cannot but be an improvement on its present. It is rapidly becoming necessary to classify electric furnaces with relation to type as well as use. Heat from the electric current may be obtained in more than one way and is used for more than one purpose. It is certain, however, that the arc, resistance, high frequency and other types of furnaces whether they be adapted to steel making, brass melting, heat treating or other industrial uses have bounded into our midst with the grim appearance of visitors who expect to remain.

The brass melting type of electric furnace is most actively taking the attention of engineers and metallurgist at the present moment. Its development has been slower than either the heat treating or steel melting furnace for several reasons. The problem is entirely different because of the fact that a varying condition of melting points, tendencies to oxidation, distillation points and the narrow limits for final pouring temperatures have complicated the issue and in one way or another retarded development. In addition, generally speaking, brass manufacturers work in smaller units than steel manufacturers. The much greater value of the product of

a brass manufactory per unit of weight naturally restricts in size as compared to the average steel producing institution. This has had the effect of forcing electrical industries to do most of the initial work and foster the development of the furnaces. There are notable exceptions to this condition, but in general it holds true.

At this time it may be said, advisedly, that in all its types and for all its uses, the electric furnace is on a plane of direct competition with any other means of obtaining industrial heat; most of the problems remaining are those of refinement or application, none of them are electrical. There is no doubt that something can yet be done to stabilize the operation of those furnaces depending on mechanical movements to gain even distribution of heat and thorough mixing. Something can yet be done in resistance type furnaces to lengthen the life of various secondary parts. In the brass industry the pyrometer is not yet perfectly adapted to any type of furnace. This is largely due to the corrosive action of zinc vapor on the protecting tubes and will no doubt soon be overcome. Generally speaking, the problem most needing immediate attention is that of linings. The speed of operation with consequent acceleration of output brings very severe conditions to bear on the linings with consequent rapid wear. This problem is now receiving a great deal of attention and the condition is improving rapidly.

The cost of operation of any type of brass melting furnace is naturally a variable for different locations and different outputs, but may be confidently assumed to be lower than other means of melting. Necessarily only a general statement can be made with reference to operation charges but the statement above is conservative and takes into consideration all the adverse conditions mentioned before.

In attempting to predict what future favor the electric furnace may find, one thing must not be forgotten, and that is, that the average man has a streak of romance in his nature and some poetry in his soul. That is just another way of saying that no matter how cold a business man may be, or how serious an engineer may consider himself, both of them are susceptible in some degree to other influences than purely business ones; in other words, everyone likes electrical contrivances and the idea of operating electric furnaces appeals to us.

Everyone knows now that there is no difference between electricity and the material which it effects in the electric furnace;

that is to say, there is no difference excepting in the arrangement of its electrons. Sir William Ramsey contented that he found Helium in an old Crooks Tube. When we remember that Helium is a product of Radium and that lead is also a product of Radium, it becomes possible to let the mind wander through the limitless possibilities of the connection between electricity or energy and material things. Is it not possible that through that peculiar hidden law which brings discoveries to light just at the time they are most needed will bring to our attention peculiar effects of the electric furnace of which we now have no knowledge; in other words, it is going to be necessary to study the effect particularly in the Arc Type Furnace of electricity upon the product. It seems highly fitting that our most remarkable method of displaying energy should be harnessed in such a way as to bring to bear the maximum amount of effect in a minimum amount of time, however, we must not forget that so intangible an agent may have many tangible possibilities which have as yet been untouched. The matter of controlling the structure of our various metals may be within our grasp.

UTILIZATION OF ELECTRIC BRASS FURNACES.[1]

By H. W. GILLETT.

Read at the Boston Meeting, June 18, 1919.

UNDER the caption "Electric Furnaces vs. Crucibles," a recent issue of the house organ of one of the crucible companies states:[2] "We understand that, as a matter of fact, the electric furnace thus far has made very little headway in the melting of brass and bronze." This statement may be either true or erroneous according to one's point of view.

Electric furnaces for steel are fairly common to-day, there being about 300 in the U. S. A. The first furnace started up 13 years ago, and in the first five years thereafter the number rose to only four.

Four years ago there was no electric brass furnace in commercial operation. To-day some forty firms are using or now installing approximately 100 electric brass furnaces. One rolling mill has about 30, though most of these are small 300-pound furnaces. One smelting and refining company is using four one-ton and four three-quarter-ton furnaces. Another firm has four one-ton furnaces and the various offices of the U. S. Mint will soon have five furnaces. Batteries of two or three furnaces are quite common.

The furnaces average much smaller than electric steel furnaces, but, nevertheless, electric brass melting has plainly made more rapid progress than electric steel melting did in its early days.

On the other hand, only about 1% of the firms melting copper alloys have as yet tried electric furnaces, and the electrically melted output is probably around 1% of the total. So one can say that much or little headway has been made in electric brass melting according to the way one cares to look at the situation.

[1] Published by permission of the Director of the Bureau of Mines.

[2] Anon. Electric furnaces vs. crucibles, Graphite, Vol. 21, 1919, p. 4451.

Other papers at this meeting will doubtless bring out the various advantages of electric melting over fuel-fired furnaces, such as obtaining crucible quality of metal without the use of costly and fragile crucibles, and doing this on a ton scale instead of the small scale of the past. They will point out the advantages of doing away with storage and handling of fuel and ashes, and show the saving of metal lost by oxidation and volatilization in fuel-fired furnaces, and the improved working conditions that are given by electric furnaces chosen with proper reference to the conditions of use. These have been shown by furnace after furnace in plant after plant.

There is one other advantage which has so far hardly received the emphasis it deserves. While the prices of coke and oil may fluctuate widely, the price of electric power is a fairly stable, predeterminable charge. Central stations, which save in rare instances, are the source of power for electric brass melting, are public utilities whose rates are regulated and thus stabilized. The foundryman can therefore predict his melting costs with accuracy for a much longer period than he can when he uses fuel.

With the advantages of electric melting now thoroughly demonstrated by commercial operation of many furnaces, no brass melter can afford to refuse to study the question of their application to his own work. Yet there are foundry conditions under which no electric furnace can economically compete with fuel-fired furnaces, or under which some types of electric furnaces cannot compete, while others can. It is possible also, to choose the right type of electric furnace for the work in hand, but to operate it so that it will bring a loss instead of a saving. Each set of conditions must be studied by itself.

Five types of furnaces have advanced far enough so that the makers can cite truly commercial performances. Various other types are in the experimental or semi-commercial stage but are not yet on the market, and a few are on the market with some at least of the experimental troubles left for the purchaser. While recognizing that there is yet no perfect electric brass furnace, and that future development may produce a type superior to those now in commercial use, prospective users may properly pay first attention only to the types which have been commercially proven in users' hands.

These types are (1) Direct arc type, with the Snyder as the

only make as yet really used on copper alloys out of the dozen of that type that are used for steel, (2) the vertical ring induction furnace type (Ajax-Wyatt), (3) the granular resistor, reflected heat type (Baily), (4) the stationary indirect arc type (Fennerfelt), and (5) the indirect arc type with stirring of the melt (Rocking furnace). Clamer,[1] Baily,[2] vom Baur,[3] Miller,[4] the writer,[5] and especially St. John[6] have previously discussed the possibilities and limitations of these various types and a mere summary is sufficient here.

The Ajax-Wyatt is the most efficient in use of power, uses up no electrodes, gives thorough mixing of the charge, perfect temperature control, and has the steadiest electrical load. It must be "primed" with previously melted metal after a shut-down and hence is not well fitted for 10-hour operation, though it can be used on 10-hour operation by keeping some current on and holding some metal molten over night. The need for "priming" makes it difficult to change from one alloy to another. It has been mainly used on yellow brass, though it is applicable to red. Its greatest drawback is that so far no refractory lining has been found that will satisfactorily withstand the action of alloys containing over 3% lead. It is best fitted for 24-hour operation on the same alloy. It could be mechanically charged.

The Baily is the least efficient in use of power, does not mix the charge, but has a steady electrical load and uses up no electrodes. This type cannot be powered as high as others without grave danger to the resistor troughs and is hence at a disadvantage as to efficient use of power especially on alloys of high melting point. It is best fitted for 24-hour operation. When used for 10-

[1] Clamer, G. H., Melting Brass in the Induction furnace, Jour. Am. Inst. Metals, Vol. 11, 1917, p. 381.

[2] Baily, T. F., Resistance type furnace for melting brass, Trans. Am. Electrochem. Soc., Vol. 32, 1917, p. 155.

[3] vom Baur, C. H., The Rennerfelt electric arc furnace, Trans. Am. Electrochem. Soc., Vol. 29, 1916, p. 497.

[4] Miller, D. D., The electric furnace as a medium for heating nonferrous metals, Jour. Am. Inst. Metals, Vol. 11, 1917, p. 257.

[5] Gillett, H. W., and Rhoads, A. E., A Rocking electric brass furnace, Jour. Ind. Eng. Cham., Vol. 10, 1918, p. 459. Melting brass in a rocking electric furnace, Bull. 171, U. S. Bur. Mines, 1918.

[6] St. John, A. M., The present status of electric brass melting, Chem. Met. Eng., Vol. 19, 1918, p. 321.

hour operation it is usually necessary to put power on part of the night to keep the empty furnace hot. It is not readily charged mechanically. It has poor temperature control, due to its heat storage and consequent sluggishness. It can be used on any alloy but is better fitted for yellow brass than for the higher melting alloys. Its greatest advantage is its simplicity of operation.

The Snyder or any other direct arc furnace is applicable only to true bronzes or other alloys low in zinc, 5% zinc being the probable limit. It is entirely impractical for use on alloys high in zinc. The only installation used for copper alloys is used on leaded bearing bronze, the new lead being added in the ladle. Much lead is volatilized from the scrap in the charge, and much fume results, giving bad working conditions. The installation of Snyder furnaces has a very poor power factor, though this is not necessary in a direct arc furnace.

The greatest advantage of the Snyder furnace in its limited field is its adaptability to mechanical charging, which aids in securing large output and hence in reasonable power consumption. One drawback is the single phase arc load.

The Rennerfelt or any other stationary indirect arc furnace is most applicable to alloys low in zinc. It has been used on alloys up to 22% zinc with fair results, but as the zinc increases above 10% the metal losses increase, and 10% zinc is probably the economical limit of its application. It has met with decided success in melting cupro-nickel, bronze and silver at the mint. It is not readily charged by mechanical means. The power consumption is fairly low.

The rocking type of indirect arc furnace is applicable to alloys of any zinc content, gives a low power consumption, is apparently efficient in small as well as large sizes, can readily be mechanically charged, has good temperature control and mixes the charge thoroughly. Its drawbacks are the single phase arc load and the possibility of electrode breakage in rocking too early if unskilfully operated.

The performance of the various furnaces properly operated, may be expected to lie in the ranges set forth in Table I.

The figures in Table I. do not in all cases agree with the catalogue claims of the makers of the furnaces, as they are based on data obtained both from makers and users. The output and power consumption depend not only on the analysis of the charge

TABLE I.—PERFORMANCE OF ELECTRIC BRASS FURNACES

Name.	Type.	Power Supply K.W.	Charge, Lbs.	Power Factor.	Material.	Output, Tons per Day on Material Given		Power Consumption K.W.H. per Ton on Material and Time of Operation Given.	Consumption of Graphite Electrodes—Pounds per Ton.
						10 Hour Operation.	24 Hour Operation.		
Ajax-Wyatt	vertical ring induction	30	300	85	yellow brass	1 to 1½	....	300–350*	none
		30	300	85	do	....	3 to 3½	225–310	do
		60	600	72	do	2½ to 3	....	250–300*	do
		60	600	72	do	do	6–7	185–250*	do
Baily	granular resistor	105	800–1500	98–100	yellow brass	2½to3½	....	400–500*	none
		105	do	do	red brass	2½ to 3	....	450–550*	do
		105	do	do	yellow brass	....	6–10	275–350	do
		105	do	do	red brass	....	6–9	325–400	do
Snyder	direct arc	100	600	35–70	leaded bearing bronze	1¾	....	380	..... (Experimental test)
		300	2000	30–60	do		12–18	260–320	3–5
Rennerfelt	indirect arc	100	500	75–90	red brass	1½	....	450–500	3–6
	do	125	1000	do	bronze	2 to 2½	....	375–425	3–5
		125	do	do	do	....	7–10	325–375	do
		300	2000	do	leaded bearing bronze	....	10–16	300–350	do
Rocking	indirect arc	40	125	80–90	red brass	¾	....	400	..... (Experimental)
		225	1300	do	do	3½	....	325–340	2¼ to 4
		225	do	do	do	....	8½	250–275	do
		300	2000	do	do	6 to 7	....	275–325	do
		300	do	do	do	....	16–20	225–275	do
		300	do	do	yellow brass	6 to 7	....	250–300	do
		300	do	do	do	....	16–20	200–250	do

* Including necessary night heating.

but also on the condition of it, i.e., whether all ingot, heavy scrap, light scrap, borings, or mixtures ,as well as on the way the furnace is operated, just as gasoline consumption varies with the roads and the way the car is run. It will be noted that there is a wide variation in power consumption among the various types of furnaces, and that for the same type, the efficiency increases with the size.

If the type of furnaces unfit for use on alloys high in volatile metals are confined to use on alloys free from or sufficiently low in such metals, and if the furnaces are kept tightly closed after the charge is melted, all types of electric furnaces will give very low metal losses indeed. No fuel-fired furnaces can compete with properly chosen electric furnaces on this score. Of course, the lost metal is mainly zinc and lead, so that the value of the loss in fuel-fired furnaces is not as great as it would at first sight appear to be when the percentage loss is considered. This loss, however, usually amounts to about as much as the fuel or labor cost, and, even with cheap zinc and lead, is worth eliminating.

In making a choice of furnaces the user must first eliminate those types which will not operate satisfactorily on alloys he must melt in them, for example, the rolling mills making yellow brass would thus eliminate the direct arc and un-rocked indirect arc furnaces, and the makers of alloys high in lead and the people who must changed from one alloy to another often, would eliminate the Ajax-Wyatt. The user should then select from the remainder the type and size of furnace which will best fit his particular work. If he has very cheap power available, the granular resistor type may be chosen over a more efficient arc furnace because of the avoidance of electrode consumption. Where power is high, the balance would be against the granular resistor type. One rolling mill may prefer to continue to pour very small billets and may find the Ajax-Wyatt exactly suited to its needs. Another may wish to operate on a larger scale and may find a one-ton rocking furnace more suitable. A maker of bronze who must take his power from a very small power plant may find that a single phase arc load would be unacceptable to the central station and hence might choose the two-phase Rennerfelt instead of the single phase rocking furnace.

The size of furnace chosen will depend on the output desired and on whether 10- or 24-hour operation is called for. While the largest size furnace that can be kept busy should be used, it is poor

economy to purchase a large furnace and then operate it with charges much under its capacity or to allow it to lie idle a good share of the time.

An electric furnace is expensive in first cost. The one or two furnaces required to melt 5 tons per day on 10-hour operation will cost from $10,000 to $20,000 completely installed. For purposes of calculation assume the cost to be $15,000. At 300 days per year the output is 1500 tons. Taking interest at 6%, the interest is $900 per year or $3 per working day, this amount being lost every day the furnace is idle. At full output the interest charge is $.60 per ton.

On the other hand, if one furnace costing $10,000 is operated for 300 days per year, 24 hours a day with an output of 16 tons, the total output is 4800 tons, and daily interest charge $2 per day, or $.12½ per ton.

On account of the initial cost and the interest charge, one should in general not have electric furnaces standing idle to handle small peaks of production in excess of the normal, but should utilize for this fuel-fired furnaces of lower initial cost.

On the other hand, the greater the number of electric furnaces which can be kept busy the lower the cost of power per ton.

Industrial power contracts usually have two factors, the demand charge and the energy charge. The first pays the power company for the equipment it must maintain to supply the maximum power needed, while the second depends on the total amount of power used.

Suppose we have a maximum demand of 300 K.W., and that the average power consumption per ton of metal is 335 K.W.H. per ton on 9-hour operation, 275 on 18-hour, and 250 on 24-hour. The total power used per day is then about 2000, 3565, or 5250 for the three cases. In a 25-day month this makes:

50,000 91,000 130,000 K.W.H. per month.

Assume that the plant, before it installed its electric furnace equipment, had a maximum demand in lights and motors, of 200 K.W., and used 20,000 K.W.H. per month for those purposes. Taking a concrete case where the power contract calls for a demand charge of $1.80 per K.W. per month for the first 50 K.W. and $1 per

K.W. per month for all over 50 K.W.; and the energy charge schedule is: 2500 K.W.H. per month at $.02 per K.W.H.; for the next 35,000 K.W.H. per month at $.08 per K.W.H.; for the next 310,000 K.W.H. per month at $.05 per K.W.H.; all over 347,500 K.W.H. per month at $.04 per K.W.H.

The 200 K.W.-20,000 K.W.H. lighting and motor power cost figures:

50×$1.50=$75.00	2500×2.0 c.=$50.00
150× 1.00=150.00	17500×0.8 c.=140.00
$225.00 demand charge	$190.00 energy charge

Total $415 or $.0275 per K.W.H., used for lights and motors. The plant now has 500 K.W. maximum demand, and 70,000, 111,000, 150,000 K.W.H., used per month on the three assumptions.

Case I.

50×$1.50=$ 75.00		
450× 1.00= 450.00		
$525.00 demand charge		
Energy— 2500×2.0=$ 50.00		
35000×0.8= 280.00		
32500×0.5= 162.50		
70000	$492.50	energy charge
	525.00	demand charge
	1017.50	total charge
less	415.00	previous charge for lights and motors
	$602.50	total charge for electric furnace power

$$\frac{602.50}{50000}=1.20;$$

The electric furnace power costs $.01205 per K.W.H.

Case II.

In Case II. we have the same demand charge, but the energy charge is:

2500×2.0	= $ 50.00	
35000×0.8	= 280.00	
73500×0.5	= 367.50	
111000	$697.50	energy
	525.00	demand
	$1222.50	total
less	415.00	lights and motors
	$ 807.50	total charge for furnace power.

$$\frac{807.50}{91000} = 0.89.$$

The furnace power costs $.89 per K.W.H.

Case III.

2500×2.0	= $ 50.00	
35000×0.8	= 280.00	
112500×0.5	= 562.50	
150000	$892.50	energy charge
	525.00	demand charge
	$1417.50	total
less	415.00	lights and motors
	$1002.50	total charge for furnace power

$$\frac{1002.50}{130000} = 0.79 \text{ c.}$$

The furnace power costs $.79 per K.W.H.

Case IV.

And if, in Case IV., the plant had three times the furnace installation figured above and used it 24 hours a day, or 900 K.W. furnace demand 1100 K.W. total, 450,000 K.W.H. per month furnace energy, 470,000 total, the charge would figure:

50×1.50=	$ 75.00	
1050×1.00=	1050.00	
	$1125.00	demand charge
2500× 2.0=	$ 50.00	
35000× 0.8=	280.00	
310000× 0.5=	1550.00	
122500× 0.4=	490.00	
	$2370.00	energy charge

$2370.00	energy charge
1125.00	demand charge
$3495.00	total charge
less 415.00	lights and motors
$3080.00	total for furnace power

$\frac{3080.00}{450000} = 0.685$ c.

The electric furnace power costs 0,685 per K.W.H.

Tabulating these we get Table II.

TABLE II.

Case	1	2	3	4
Hours	9	18	24	24
No. furnaces	1	1	1	3
K.W.H. per ton	335	275	250	250
Power price c. per K.W.H.	1.205 c.	0.9 c.	0.89 c.	0.685 c.
Cost $ per ton for power	$3.92	2.45	1.98	1.71

This table shows the advantage of continuous operation of electric furnaces, as well as that of large installations. The exact figures will vary in each particular case, but the ratios will remain approximately the same.

The cost of power is in most cases the largest single item in melting costs in electric furnace practice. Every effort must then be put forth to keep this cost down. The way to do this is to keep the furnace at work at its job, which is melting metal. This

is important on 24-hour operation, but even more so on 8 to 10-hour operation, for an extra heat per day on single shift operation means that it is obtained at the end of the day when the furnace has recovered from cooling off through the night. Any furnace will illustrate this fact. Take an actual day's run of a small Rennerfelt on red brass for example:

Heat.	Charge. Pounds.	Total time.		Arc on		Idle time.		K. W. H. Used.	K. W. H. per 100 lbs.	Notes.
		Hrs.	Min.	Hrs.	Min.	Hrs.	Min.			
1	497	2	45	2	05	...	40	211	42	Furnace at red heat from previous day's run
2	522	1	45	1	25	...	20	130	25	
3	527	2	55	1	10	1	45	105	20	Delay waiting for molds
4	523	1	25	1	05	...	20	106	20	
5	394	1	25	1	10	...	15	94	25	Waiting for molds —so held power input low
Total	2463	10	15	6	55	3	20	646	26	Av. or 52 K.W.H. per ton

This could have been run as follows, by eliminating all delays:

Heat.	Charge, Pounds.	Total Time.	Arc on	Idle Time Charging and Pouring		K.W.H.	K.W.H. per 100 lbs.
				Hrs.	Min.		
1	525	2 : 10	1 : 55	..	15	215	41
2	525	1 : 40	1 : 25	..	15	130	25
3	525	1 : 25	1 : 10	..	15	105	20
4	525	1 : 20	1 : 05	..	15	100	19
5	525	1 : 20	1 : 05	..	15	100	19
6	525	1 : 20	1 : 05	..	15	100	19
	3150	9 : 15	7 : 45	1	30	750	24 av. or 4.80 K.W.H. per ton

The elimination of delays thus gives a 25% increase in output in an hour's less time, and decreases the cost of power per ton by about $.40.

With the exception of the granular resistor type in which it is difficult to hold metal after it is once ready to pour because the response to changes in power input is so slow, it is possible to hold metal ready to pour as long as one likes in any of the electric furnaces. This is a convenience in an emergency, but it is very poor practice from the point of view of furnace efficiency.

The use of as large ladles as it is practical to discharge the furnace into, so that the furnace is idle the shortest possible time during pouring, combined with mechanical overhead charging (in such furnaces as the Snyder and the rocking type which readily allow it) allows the furnace to work at its job of melting the greatest possible proportion of the time. On charges of all borings, especially in case of hand charging, briqueting would be desirable. Bundling of wire and similar scrap is almost essential. An electric furnace is like a motor truck in that the less time that is lost in loading and unloading, and the greater the number of hours per day it can be used, the lower the cost per ton melted in the one case and per ton mile in the other. Cutting down on waste time pays even better with the furnace than the truck, because the more power the furnace uses in 24 hours, the lower the cost of the power per unit while gasoline for the truck does not come much cheaper when bought in larger amounts. Another way that power can be saved in electric melting, is to operate on a definite schedule of power used. The Ajax-Wyatt takes power at so steady a rate that a time schedule works just as well on that type, but the granular resistor furnace and the arc furnaces may vary considerably in rate of power input. After a few test runs, one can, for any particular alloy, particular proportion of ingot, scrap and borings, and for any particular weight of charge, make out a perfectly definite schedule of K.W.H. needed on each heat. In 10-hour operation the K.W.H. per heat will be higher in the morning and approach or reach a lower constant figure at the end of the day.

By adhering to such a schedule and running on K.W.H. input, instead of on a time schedule at a supposedly constant but actually variable K.W. input, the heat can be brought out with astonishing regularity as to temperature. Each furnace should have its in-

dividual K.W.H. meter, and one readable to certainly not less than 5 K.W.H. and better to 1 K.W.H. With individual K.W.H. meters the performance of each furnace in a battery, and of each furnace tender can be watched. The K.W.H. meter is as important as the speedometer on a motor car or truck. Not all furnace makers supply them, but each furnace should have one.

Inasmuch as the heat losses through the walls and the electrodes are approximately constant even though the rate of power input may change, it is obvious that the higher the rate of power input, the more of it is usefully employed in melting. Suppose a furnace takes 100 K.W. and loses 35 K.W. through shell radiation and electrode losses, 65 K.W. then do useful work. If the same furnace is given 125 K.W. it may lose 37½ K.W. in shell and electrode losses, but 87½ K.W. do useful work. The furnace will do one-third more work in a given time at the higher rate. The upper limit of rate of input is that at which the local temperature is so high that refractories fail or that local overheating of the metal and consequent loss of volatile metals occur. It is quite probable that on the larger furnaces automatic control of power input would be desirable.

From the considerations noted above it is plain that the advantages of electric furnaces are most marked where a number of large furnaces or of small efficient furnaces can be used and especially where they can be used 24 hours a day. Rolling mills, smelting and refining plants, brass foundries of large manufacturing plants and the larger jobbing foundries, are the plants which can most obviously use electric brass furnaces at a saving in melting costs. Such plants should think twice before deciding to go on with fuel-fired furnaces.

The smaller plants and jobbing shops having a small output and a variable one, especially if they are so located that power will cost much over $.01¼ per K.W.H., should think twice before installing an electric furnace. Even this class of furnace users may often find that the electric furnace will save some money in the long run, although under normal peace conditions the amount saved will be small compared to what it was during the war or may be at present.

Whether electric brass melting has or has not as yet made much headway, it at least had a foothold and apparently a firm one. It will be surprising indeed if inside the next decade the ratio of

brass melted electrically to that melted by fuel does not surpass the ratio of steel melted electrically to that melted by fuel. All metallurgists will agree that the electric steel furnace is here to stay. They will soon agree that the electric brass furnace is here to stay, too.

PROBLEMS ENCOUNTERED IN ELECTRIC FURNACE PRACTICE.

By P. E. McKINNEY.

Read at the Boston Meeting, June 18, 1919.

THE unprecedented demand for steel and steel products during the past four years has resulted in a number of firms entering into the production of steel either on a large or small scale, in which connection the electric furnace, on account of its apparent simplicity, has become more generally used than any of the other processes for manufacturing steel, at least in so far as the small medium tonnage producers were concerned.

With the more or less universal use of the electric furnace, especially in many cases by firms who had never previously been interested in the manufacture of molten steel, many problems have been encountered, and the reputation of electric steel has suffered due to the fact that some problems encountered were not easily solved.

A great deal of discussion has arisen from time to time regarding the comparative quality of electric steel as compared with open hearth steel, without always taking into consideration that all electric steel is not similar in quality, any more than all open hearth steel is similar, and without regard to the fact that the metallurgical practices followed in the production of high grades of steel are just as important in one case as in the case of the other. There is no more reason to compare highly refined electric steel with electric steel which was simply remelted scrap with the minimum amount of refining, than there would be to compare the product of an open hearth furnace which had been boiled for a long time, highly refined and finished with a view to the production of the highest grade of forging steel with the product of an open hearth furnace in a mill which was manufacturing commercial grades of

open hearth steel for use in the manufacture of rails, structural materials, etc.

In the manufacture of steel in an electric arc furnaces it has been regardless of the type of furnace used, the matter of refining the heat is of just as great importance as in the case of steel manufactured by any other process, in fact on account of the harm which may be done by overheating the steel in an electric furnace the importance of super-refining is more pronounced than in the case of open-hearth steel. In cold charge melting it is quite easy when starting with a fairly clean grade of scrap to make the process one of simply remelting the charge which, with the addition of small amounts of ferro-alloys, is then termed finished electric steel, no attention having been given to the conditioning of the slag or metal so as to produce the highest quality from a metallurgical standpoint, and such grades of steel when going on the market as electric steel have frequently reflected on the general quality of all electric steel, regardless of the processes used in its manufacture. In fact at the present time there is a tendency on the part of some specification writers to prohibit the use of electric steel where alloy steels of highest quality are needed, which it is believed is not fully justified, as, generally speaking, it is possible to make as good or better grades of alloy steel in the electric furnace than is possible even in the crucible process.

In the manufacture of high-grade electric steel, whether alloy steel or straight carbon steel, the process should be considered as being made up of three distinct operations. First, the melting; second, the refining; and third, the pouring; each operation being an important one and having considerable bearing on the ultimate quality of the product.

In the manufacture of steel in an electric arc furnace it has been found desirable to melt the cold charge as rapidly as possible, using all the current and as hot an arc as the charge will absorb, as the melting operation is one in which excessive caloric input in the furnace is not objectionable. During the time of melting it has been found desirable to add to the charge along with the lime, which is used for dephosphorizing, sufficient ore to reduce the carbon content of the bath from .05 to .10 per cent, in which condition the metal will become most thoroughly dephosphorized. When the carbon content has been reduced to the above point, the highly oxidizing slag which is formed during the melting operation is

removed by skimming off, leaving the metal in the furnace practically clean from slag, which ends the melting operation and is the beginning of the refining operation.

The first step in the refining operation is the addition of the necessary manganese in the form of ferro-manganese which is added directly in the bath, together with the necessary lime to make up the refining slag. When manganese is added at this stage of the operation practically all of it is oxidized and goes into the slag, but the same is again recovered in the bath as metallic manganese during the subsequent refining operation. In order to bring the slag into a fluid and workable condition, small amounts of fluorspar are added, after which the refining operation is proceeded with, which consists of adding in small quantities powdered ferro-silicon and powdered carbon, which are added on top of the slag close to the electrodes with a view to the formation of the maximum amount of calcium carbide. The additions of silicon and carbon are continued until a perfect so-called white slag is produced, and at which time the slag should be practically free from manganese. The use of ferro-silicon in conjunction with carbon in the conditioning of the slag is considered highly advantageous, as it greatly aids in the quick formation of calcium carbide in the slag and therefore tends to desulphurize the metal to a much greater extent, and also to greatly reduce the amount of manganese carried in the slag.

If super-refining in this stage of the operation is carried along to a sufficient extent it is readily possible to reduce the manganese content of the slag to considerably below .50 per cent, and under no circumstances should a manganese content of over 1 per cent be present in a slag after refining. Such a slag will desulphurize the metal to most any desired point, it having been found readily possible to obtain sulphur content in the finished steel below .02 per cent, and in some cases the sulphur content of the finished steel was even as low as .01 per cent and under, notwithstanding the fact that the original charge may contain up to .08 per cent sulphur. A good refining slag will absorb in excess of 1 per cent of its own weight of sulphur. After the desired condition of slag has been obtained, samples of the metal are taken in a hot spoon and allowed to solidify slowly with a view to determining the state of deoxidation of the metal, after which the necessary ferro-silicon is added to the bath and further hot spoon tests are taken for the

purpose of determining the condition and temperature of the metal. The current is then cut from the furnace, and the metal allowed to cool in the furnace to a predetermined point, tests being taken for solidification from time to time. During the steel refining operation just sufficient current is used to hold the metal in a good state of fluidity, superheating being avoided both on account of the waste of current and to avoid excessive attack on the lining of the furnace. When the metal has cooled to the desired temperature the same is tapped into the ladle, which ends the refining operation.

In pouring basic electric steel it has been found desirable to hold the steel in the ladle for as short a time as possible, all cooling to be done in the furnace, as the basic slag attacks the ladle most violently, causing trouble to stopper rods, nozzles, etc. The pouring operation should be conducted with a view to cooling the metal in the ingot as rapidly as possible. Generally speaking, slow pouring at a low temperature being considered the ideal condition, too much stress cannot be placed on the dangers attendant to pouring hot metal at a rapid rate, as such metal will almost invariably contain defects which will develop during subsequent forging or heat treatment. Many cases have been noted where perfectly refined electric steel, and steel which was otherwise entirely satisfactory, was poured at temperatures higher than any that it would be possible to obtain in open-hearth practice, the slow solidification of such steel being the sole cause for the defects subsequently found.

In conclusion, it might be stated that the problems which now exist in electric furnace practice for the manufacture of steel are nothing more than metallurgical problems, the same as exist in Bessemer, open-hearth, or crucible practice, and the solution of the same lies in the study of the chemical and metallurgical reactions involved, and that consideration of the same from its metallurgical as well as its electrical features will greatly aid in placing electric steel in the position it merits. It is a well-known fact that some of the very best grades of steel made in this country to-day are made by the electric process by companies who have studied the process and have perfected it in all of its metallurgical features.

ELECTRICAL CONSIDERATIONS OF THE ELECTRIC FURNACE INSTALLATION.

By N. L. TOWLE.

Read at the Boston Meeting, June 18, 1919.

NOTWITHSTANDING the very large amount of electrical energy which is to-day utilized solely in the production of heat in the electric furnace, the electrical characteristics of furnace installations are, for the most part, realized only vaguely by furnace operators. During the war, under the pressing needs of production, electrical considerations of the furnace installation which, under normal conditions, would have received deserved attention, were subordinated to features of mechanical design, to first cost enticements, and even to installation convenience. To-day, however, the United States is returning to a normal competitive production basis, and the users of the electric furnace will find it pertinent to consider not only the design and operating features of the furnace, but of equal importance, the design and operating characteristics of the furnace installation from a purely electrical viewpoint. It is proposed to treat herein in more or less general fashion, of power factor and of power input regulation as two electrical considerations of the electric furnace installation which will be reflected in the cost of furnace operation.

The electric furnace of arc characteristic, is a load of practically constant reactance, and variable resistance. It may be shown that maximum input to the furnace is obtained when the resistance component is equal to the reactive component, that is, when the power factor, the co-sine of the angle between current and voltage waves, is 0.707. In this case, the reactance in per cent is 70.7. With power factors less than 70.7 per cent, the effect of reactive voltage drop more than outweighs the factor of input due to the increased current, so that the energy expended in producing heat decreases.

However, were a power factor of 70 per cent, to obtain in a furnace load, it would mean that the capacity of the electrical equipment would have to be 141 per cent that required for supplying the true power component of the load. Obviously, the central station will not tolerate loads of such character in capacities of ordinary furnace practice, nor does the furnace operator care to purchase equipment of 41 per cent excess and useless, wattless capacity. On the other hand, the arc furnace will require a certain amount of reactance in its circuit, which will function to store energy momentarily and return it to the circuit during the period of the cycle when the alternations pass through the zero value. We may say that approximately 30 per cent reactance, corresponding to 95 per cent power factor, must be inherent to the electric arc furnace circuit in order to stabilize its operation. Evidently, we are now limited by purely theoretical considerations to a power factor not less than 70.7 per cent and not greater than 95 per cent. From an electrical standpoint, the electric arc furnace must always operate between approximately 95 and 70 per cent power factors, and commercial furnaces of all types will usually operate within this range.

The power factor influences the capacity of electrical equipment, because alternating current machinery is rated according to the product of volts and amperes (K.V.A.) which must recognize the limiting value of capacity as imposed by the current and attendant heating effects. This is true not only of the electrical machinery which supplies power from the central station, but of the transformer which steps down the voltage for furnace utilization. The heating effect of current in a circuit is proportional to the square of its value, so that as the power factor decreases, losses due to current flowing through resistance of the conductors will increase very rapidly. Evidently, it is to the first cost advantage of the furnace operator to secure the transformer of minimum K.V.A. rating which will perform his service. The lower then, the reactance of the circuit, the higher will be the power factor, the lower will be the first cost of the transformer, and the less will be installation losses.

The second effect of power factor is manifest in power rate charges which are made by central station companies. In general, the power factor charge has not been standardized throughout the country, but of the variety of methods used, nearly all act

to increase the maximum demand rate in one or another manner. A typical method is to require that the consumer pay a proportionate increased rate as the power factor decreases, and at the same time be allowed a decreased rate when the load is above a defined power factor per cent. Thus, for a 1000 K.W. load on a certain system, a power factor of 90 per cent would be required, the consumer paying 90/85ths the normal maximum demand rate when operating at a power factor of 85 per cent; or if operating at 93 per cent, paying 90/93rds the normal maximum demand charge. In general, the larger the furnace load, the lower will be the inherent power factor and the greater will be the incentive offered to maintain a high power factor standard.

The reactance which lowers the power factor of a furnace load is made up of two parts: First, that which is inherent to the transformer, and second, that which is inherent to the low voltage lead arrangement. We will not here consider reactance coils which may be required in furnaces of very small capacity, for arc stabilizing purposes. The reactance of the furnace transformer will be small compared to the reactance of the low voltage lead arrangement.

The inherent reactance of electric furnace transformers will vary from 5 per cent upward, depending upon the type and particular design features. On small capacity furnaces, the inherent reactance of the transformer may, as an economy, be a considerable portion of the total reactance of the circuit, since at the relatively small currents the low tension bus layout itself will have corresponding small reactance. It is, however, significant that when the electric furnace comes into the larger commercial sizes, the low voltage leads must be arranged with special care in order that their reactance remain within reasonable limits. In furnaces of commercial capacities, therefore, it may be said that more than sufficient reactance will always be found in the low tension leads to stabilize the furnace arc, and moreover, that the inherent reactance of the transformer should be reduced to a minimum in order that the sum of bus and transformer reactances may not exceed more than is essential for successful operation, and that the power factor of the load may be maintained as high as possible.

Providing that the transformer is guaranteed by the manufacturer to be able to withstand short-circuit at its low voltage terminals with full line potential impressed on the high voltage

winding, the inherent reactance of the transformer may be said to be a measure of the transformer's reliability. Thus, a transformer having an inherent reactance of 12½ per cent will upon short-circuit, pass a sustained current 8 times normal, with full potential impressed on the high tension winding. The stress set up between coils of the winding being proportional to the square of the current will, under this condition, be 64 times normal. On the other hand, a transformer whose inherent reactance is 5 per cent, will, under similar conditions, pass a sustained current 20 times normal and the stresses set up will be 400 times normal. Momentarily, this condition is much exaggerated should the short-circuit occur at the peak of a voltage wave, allowing 16 or 40 times normal current to set up mechanical stresses of 256 or 1600 times normal in the respective transformers. Actually, the latter condition may never arise, but the significance of the short-circuit guarantee which must allow for the worst possible condition, indicates the superior mechanical design which must prevail in transformers of low reactance which are able to withstand such conditions of service.

A transformer with inherent high reactance will act to lower the power factor of a furnace circuit appreciably. Consider that the lowest reactance which may be secured in the low tension leads is 35 per cent. With a transformer having 12½ per cent inherent reactance on a unity power factor load, the power factor of the circuit would be 88 per cent. With a 5 per cent unit, the power factor of the circuit would be 91.7 per cent. The difference in power factor secured here by using a low reactance transformer is 3.7 per cent; or on the basis of a 90 per cent power factor schedule, the low reactance transformer would secure a decrease in the maximum demand charge of some 4 per cent. Considering the refinements that are to-day being practiced in power factor correction, this decrease would seem a saving well worth while. Also other things being equal, the low reactance transformer should be the better unit for electrical and mechanical performance.

The great portion of the furnace circuit reactance lies in the low voltage lead arrangement. It is not proposed here to go into detail over various methods which secure by a rational design the lowest possible bus reactance and highest power factor. It is, however, worthy of note that on the larger installations, energy which can be conveyed to the furnace with a single electrode group

is limited by the inherent reactance of the bus leads. Low tension bus reactance, therefore, limits the capacity to which furnaces having a single group of electrodes may be built. The solution has been to provide several groups, each having a number of electrodes and thus allowing smaller currents to the furnace over a number of paths. It is good economy to spend time and thought in planning the low voltage lead arrangement for furnaces of commercial capacities, when by so doing a considerable increase is secured in a power factor which is necessarily low. The value of reactance may be calculated from preliminary bus layouts, and, by carefully comparing a number of different arrangements, the layout which will secure the highest power factor may be deduced. Incidentally, it is to the credit of workers in this field that calculations when checked with the completed installations, have shown identical values for the power factors obtained.

The demand charge of the central station is based upon the maximum power taken over a specified short time interval. Thus, a power contract may charge a certain rate per K.W. for the maximum demand over a five-minute period which occurs during a given month. By a relatively high charge for loads greater than the normal demand, the central station is able to suppress short time loads on its system and to improve the average power demand. In general, the electric furnace is inherently a fluctuating load, so that a reasonable constancy of power input can be secured only by use of automatic regulation.

Under conditions of automatic regulation, the extent of the maximum demand and, therefore, the demand charge will depend upon the closeness with which the automatic device will hold the furnace input to a normal base line setting. The regulation of a sluggishly acting device will not only cause the maximum demand to be increased, but will by failing to maintain the furnace input at normal, greatly decrease production. The use of an automatic regulating device which acts only on a large input variation will then mean a double economic loss to the furnace user. Furthermore, the type of furnace process seriously affects the closeness with which an automatic regulating device may function, so that a regulator which may give satisfaction on characteristics of a carbide furnace will not operate closely on steel furnace service. Furnace operators frequently fail to realize the limitations of automatic regulating devices which may show a constant line input

on one service, and yet be able to regulate only with a wide per cent variation on other applications.

On a severe fluctuating service, automatic regulators are occasionally found which operate to hold the load within 15 per cent. Contrasted with a regulator which would hold the power input to within 4 per cent, the power maximum demand charge would evidently be some 10 per cent greater than good operation would allow. Experience has shown that the furnace output might often be increased as much as 20 per cent by the use of a regulator holding the power to the furnace to within a few per cent plus or minus variation. This will be typical of the economy available through the use of proper automatic regulating equipment, and should indicate that first cost of any automatic regulator must not be weighed in terms of the size and cost of the furnace itself, but in terms of the extent to which its adoption will lower power charges and increase furnace production.

The automatic current regulator is most generally used in connection with electric furnace control. However, on furnaces which are not of the movable electrode type, automatic regulation of power input is secured by voltage control. Here, also, closeness of regulation is a factor in the determining production, and the extent to which variation from a straight line characteristic is permitted will be reflected in the power charges. In power input regulation by voltage control, the electric furnace is most efficiently utilized when voltage is varied by small increments to suit a gradual change of the needs of the process. With former practice, a number of switches cutting in more or less on the transformer winding were used to secure an approximate average heat condition as the process progressed. The best that can be realized by this method, however, is only an average, and results both in too great demand charges and production below the maximum possible. It is significant that to-day there is increasing use of a modified induction regulator giving exact power requirements over a wide voltage range, and permitting the closest sort of voltage control.

In reasonable power factor limitation, therefore, and in close power input regulation, lie two electrical factors which may well be accorded deserved weight in an electric furnace installation since to a considerable extent these factors will affect the economics of an electric furnace process both by increasing production and by lowering electric power charges.

ELECTRIC FURNACES OF THE RESISTANCE TYPE FOR MELTING NON-FERROUS ALLOYS.

By T. F. BAILY.

Read at the Boston Meeting, June 18, 1919.

All of the furnaces described in this paper are of the resistance type—their heating element consisting essentially of granular carbon placed in a silicon carbide trough—and are of the type that have for a number of years been in common use for heat treating and annealing steel, some of the most notable of these heat treating furnaces being the equipment supplied some years ago for the heat treatment of draw bar knuckles, and during the last year installations for the heat treatment of Liberty airplane motor crank shafts (over half of which were so treated) and those for the heat treatment of cast steel anchor chain (all of which material was heat treated in this type of furnace).

The success of furnaces of this type in annealing and heat treating, indicated that furnaces of similar design with detail modifications would fulfill the requirements for the melting of brass and other non-ferrous alloys; and, after a careful survey of the various requirements for brass melting furnaces, the type of equipment described in this paper was developed.

The first of these furnaces (Fig. 1) was put in commercial operation nearly three years ago at the plant of the Lumen Bearing Co., Buffalo, N. Y., for the melting of "Lumen"—a metal, which on account of its high zinc content could not be commercially melted in open flame furnaces, and even in crucible type furnaces could only be melted with a relatively high zinc loss.

The principal factors taken into consideration as necessary to the development of a successful brass melting furnace were (1) the metallurgical requirements, (2) the mechanical features, (3) the electrical characteristics, (4) the thermal efficiency, (5) the commercial economy as compared with other types of melting equipment.

The obvious advantages to be found in an ideal electric furnace over fuel fired types of melting were: (1) the elimination of crucibles, which are one of the principal costs in the melting of brass in pit type furnaces, (2) the reduction in metal loss when

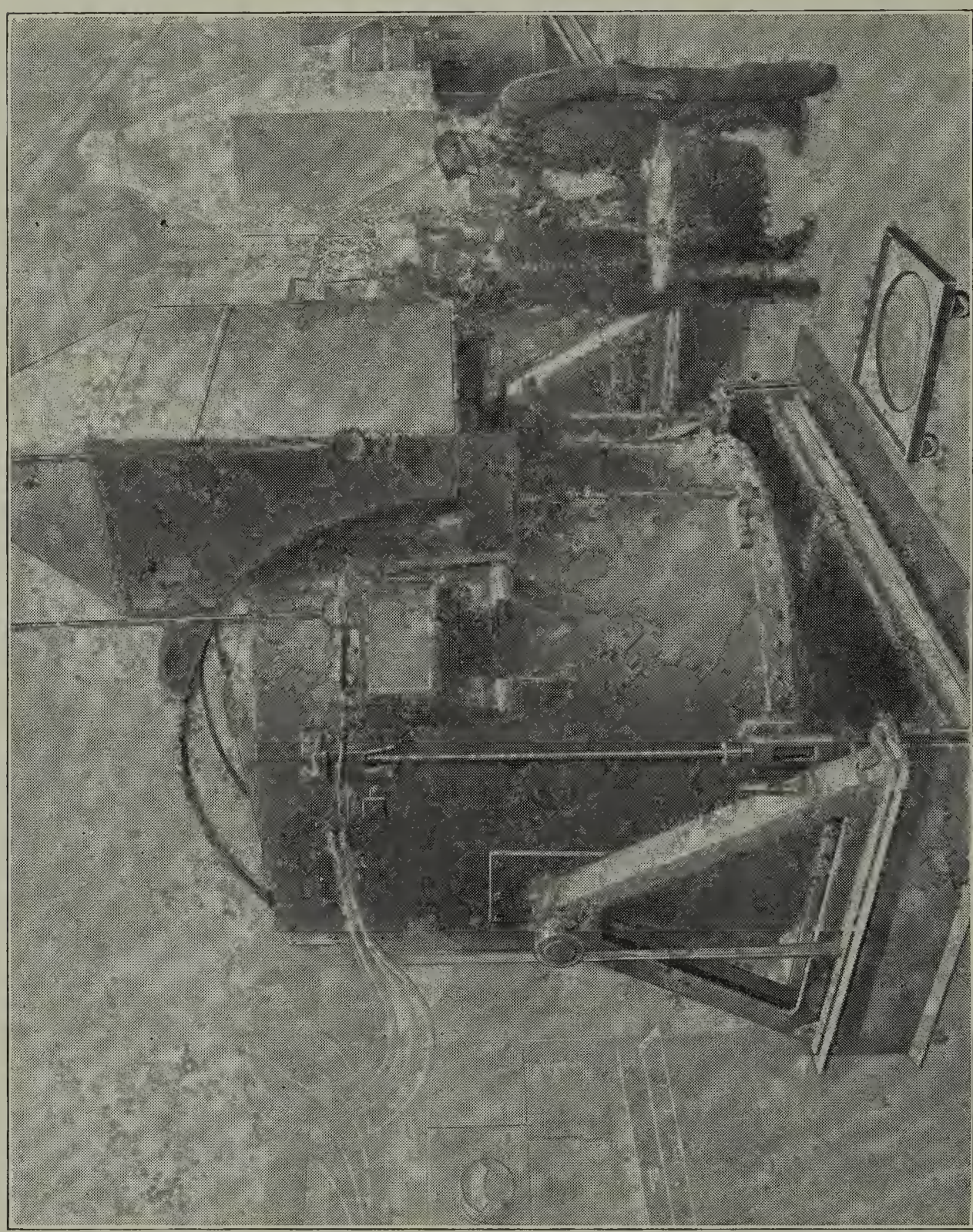

Fig. 1.—Three Furnaces at the Lumen Bearing Company, Buffalo, N. Y. The first electric brass melting furnaces in America.

handling zinc mixtures, on account of the slight vacuum under which all pit type furnaces are required to operate, (3) the ability to maintain a reducing atmosphere in the furnace at all times which is impossible in fuel furnaces when operating with any degree of fuel efficiency, and (4) the fact that copper alloys, as well as

copper, have a high affinity for the absorption of undesirable gases when in their molten condition, this being equally true of other alloys and non-ferrous metals, such as aluminum.

Before the development of these furnaces for brass melting, a careful survey was made as to the adaptability of the more common types of furnaces then widely in use in the melting of steel, to determine whether such furnaces could be readily and successfully adapted for brass and other non-ferrous melting operations; and if they could be, with what degree of commercial efficiency, as compared with the resistance type of furnace we then had under consideration.

These investigations took into consideration the very compact form of the arc furnace, the simplicity with which the heat from the arc is imparted to the bath, the high thermal efficiency that could be obtained with rapid melting, and the fact that the arc furnace had already been highly developed for steel melting, both from a mechanical and from an electrical standpoint.

Observation of the induction type furnace for melting steel as it might be applied to the non-ferrous industry indicated the high economy with which these furnaces could be operated, even as compared with arc furnaces, the simplicity of the electrical principles involved, so far as they applied to the mechanical apparatus, and the ability to keep the furnaces substantially closed.

The objectionable features of the arc type furnaces taken into consideration were, in the first place, from a mechanical standpoint, the necessity of having movable electrodes requiring constant adjustment; the difficulty of keeping the furnace tightly closed at the point where the electrodes entered the furnace, and at the same time preventing the electrodes sticking at this point; and from a metallurgical standpoint, especially important when considering the melting of metals containing zinc, the undesirable effect of the highly localized temperature produced by the arc.

The arc type furnace for brass melting was also open to the same objections met with in steel furnace practice with regard to refractories, the accepted practice in the steel industry in order to minimize this difficulty being to use electrodes of relatively large section placed with their axes vertical to the level of the bath, so as to have the arc itself "hooded" to as great an extent as possible by the electrodes themselves.

From an electrical standpoint, the accepted type of steel melting

furnace, when supplied with automatically operated electrodes, is able to give fair power characteristics, both as to power factor and load factor, especially furnaces of the three-phase type, although this favorable condition is not to be found in single-phase furnaces with hand control.

An examination into the advisability of melting brass in the usual arc type steel melting furnace showed conclusively that this type of furnace without modifications could not be successfully operated without a thick slag bath lying between the metal and the arc, and while some success was obtained by the use of this thick slag cover, the inconvenience of operation incurred by this feature was such as to make it decidedly objectionable.

In considering the steel melting furnace of the induction type for brass melting, the objectionable features to be found, when considering it as applied to the brass industry, were the difficulty involved in starting the furnace with cold metal; the necessity of keeping some metal in the furnace at all times and the current on; the likelihood of short circuiting on high lead mixtures; and the narrow channels necessary in order to hold the secondary current within reasonable range, a condition which was aggravated, due to the high electrical conductivity of non-ferrous metals as compared to steel.

From an electrical standpoint, while the induction furnace has an advantage over the arc furnace due to the absence of electrodes, a serious complication was met with in electrical characteristics, on account of the bad power factor condition, which seemed to indicate that furnaces of this type could not be successfully built in the larger sizes.

When considering the use of the true resistance type furnace as it might be applied to the melting of non-ferrous metals, the following points are given consideration:

1. That the metal should be contained on a true open hearth, and that the heating element should be entirely independent of the metal.

2. That the heating element should be such that there would be a comparatively slight difference in temperature between this heating element and the bath, so as to overcome the objectionable features offered by the arc type furnace.

3. That it should be feasible to tightly close the furnace in order

to keep the molten metal under a pressure, however slight, and to prevent, as well, any draft of air through the furnace chamber.

4. That the electrical characteristics of the furnace as applied to power factor should be such as to overcome the objections present in the induction furnace, and that the wide power variation present in the arc furnace should be, if possible, eliminated.

5. That the furnace should not be subject to rapid changes in temperature from the most desirable ruling temperature for any particular melting operation.

6. That the furnace should be as compact as possible, in order to reduce radiation losses to a minimum.

In this latter case, while the resistance type furnaces about to be described require a somewhat larger shell for a given melting capacity than either the arc or induction furnace, the absence of the highly localized temperature eliminates such a serious condition with regard to refractories; and the lower temperature at which the resistance element in a resistance type furnace operates, enables a higher degree of heat insulation to be used, so that the thermal efficiency of resistance type furnaces compares favorably with other types—with the exception, perhaps, of the induction furnace, whose higher thermal efficiency is seriously offset by its higher renewal and repair cost.

One of the mechanical features taken into consideration before determining on the type of furnace to be used was whether it was necessary, in order to obtain perfect alloying, to provide some oscillating motion, such as was originally used on the Stassano steel furnace; but when considering that substantially all copper alloys, with the exception perhaps of lead, diffuse completely when the the proper temperature and melting conditions are reached, this additional complication was dispensed with, the only agitation required being the stirring in of the spelter previous to pouring, and this stirring is only required in order to facilitate the more rapid diffusion of the alloy.

The only materials in the furnaces described in this paper that need regular renewal are:

1. The resistor troughs themselves, which are made of carborundum fire sand and water glass, and were formerly tamped into place in the furnace with the aid of wooden forms, but are now made in sections at our works and baked ready for placing into the furnaces.

2. The electrodes for leading the current from the cable terminals through the furnace walls and into the resistor material.

3. The resistor material itself, which consists of broken carbon crushed to about ¼-inch mesh.

Under average working conditions, the fire sand troughs, and a pair of electrodes will last from three to four months, while the resistor material requires additions to it of fresh material every two weeks. This latter is accomplished in the small tilting furnace by raising the roof through the medium of three screws which are operated simultaneously by a hand wheel on the back of the furnace operated through sprockets and miter gearing.

Some months ago for a period of time, some difficulty was experienced with resistor troughs, but a careful and exhaustive investigation brought to light that this trouble was experienced only when the analysis of the fire sand indicated an imperfect mix; and since all this material must now pass laboratory inspection, no difficulty is experienced from this source.

The furnaces now to be described are built in two regular types, the first, which found wide applications in foundries, is of the round tilting type; while the other, of rectangular shape, is the type used for melting large tonnages and for smelting operations.

The round type (shown in Fig. 2) is provided with a circular resistor trough with the electrodes coming into the trough diametrically opposite each other, the resistor material being renewed by lifting the roof, as previously stated; while in the rectangular type, the resistor troughs are two in number and placed longitudinally along each side of the hearth, and are, therefore, straight. The resistor material, in this case, is charged by means of long shovels through a door at each end of the furnace and directly above the trough. A section of this round type furnace is shown in Figure 3. This furnace is a standard 105 K.W. trunnion type with a rated hearth capacity of 1500 pounds and a melting rate of 600 pounds per hour. These capacities, however, have been in numerous cases materially exceeded, as much as two tons having been placed in a furnace at a time, and the melting rate increased to more than 1000 pounds per hour, when operating under exceptionally favorable conditions.

The furnace consists of a steel shell made of ½-inch plate seven feet in diameter and approximately 6 feet high, mounted

on the usual cast iron trunnions and brackets, and having the usual hand wheel tilting mechanism.

The interior wall of the furnace is substantially 5½ feet in diameter, with a wall of circular brick about 4½ inches thick. The space between this brick wall and the steel shell is filled with kieselguhr insulation. The steel roof ring is adapted to hold

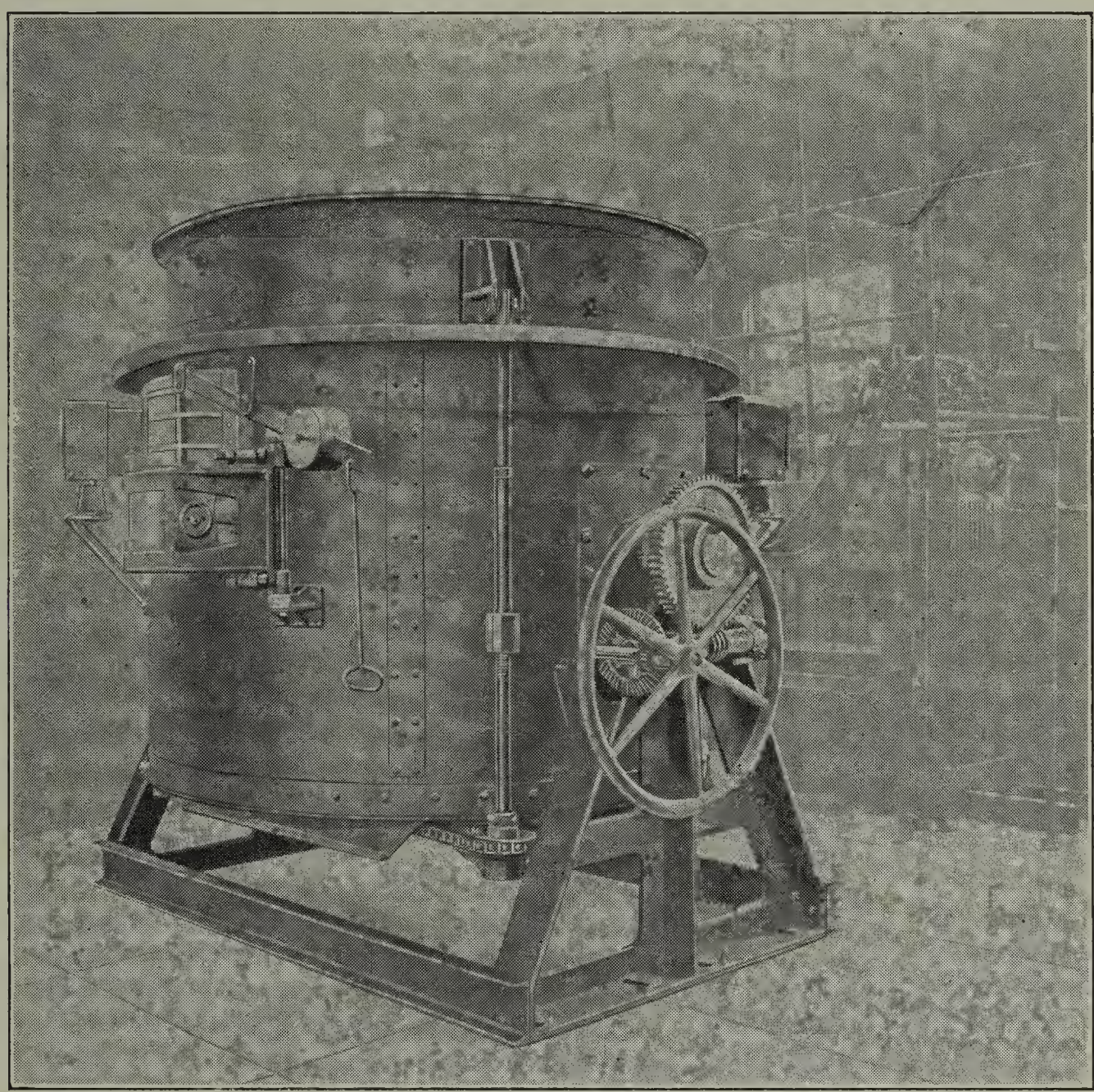

Fig. 2.—Complete Installation of a Single 105 K. W. Brass Melting Furnace.

securely the skew backs of the domed arch, and is provided with a lower fin for dipping into the sand seal. The space above the trough dome and below the steel top is also filled with kieselguhr in the same manner as between the fire brick walls and the steel shell of the furnace proper.

The hearth is located in the bottom of the furnace and is com-

posed of a mixture of carborundum fire sand and plastic clay material bonded with silica of soda. The resistor trough is located above the bath and completely encircles the rim of the hearth line, although located a considerable distance above it, and is set on fire brick piers, so that the heat from the lower part of the fire sand trough is readily dissipated from this part of the trough within the furnace chamber.

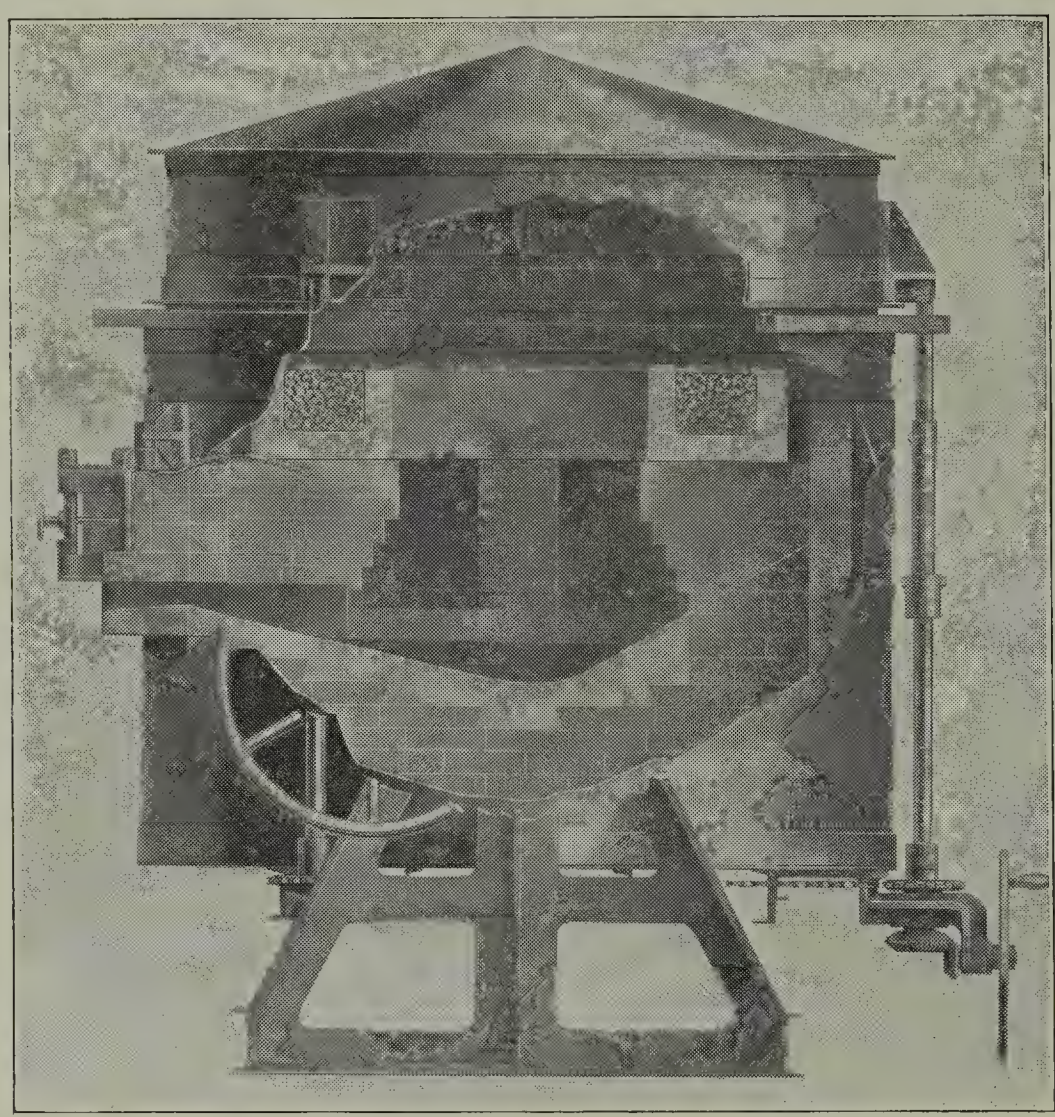

Fig. 3.—Cross-section of Standard Melting Furnace, showing resistor trough mounted on brick piers. 1500 pound hearth, pouring spout, and plug type door.

This feature is of vital importance in the successful design and operation of resistance type furnaces, as all early experiments with furnaces of this type without this feature resulted in failure.

The resistor material contained in this trough, and into which the electricity is introduced by means of the two carbon electrodes, as previously mentioned, radiates the heat generated in it to the roof of the furnace and thence down onto the hearth; while the heat coming from the lower part of the trough between the sup-

porting pillars is also radiated directly to the bath. That this resistor ring has a radiating surface of over forty square feet accounts for the fact that there is no highly localized temperature in this furnace.

The control of the furnace is obtained by means of impressing various voltages on the low tension side of a special transformer across the furnace terminals by means of a special selective oil break switch. The special transformer supplied with each furnace is wound for any convenient line voltage, while the secondary of the transformer is provided with various voltage taps, usually giving a voltage ratio of two to one on the low tension side. By means of this arrangement, the electrical losses are reduced to a minimum, and an accuracy of control obtained that is not possible by other types of equipment, and it is readily possible to operate over long periods of time without a greater variation in electrical input than a few per cent.

The only opening to the furnace, which is used for charging the material is provided with a swing type plug door, the hinges being made of cast steel and attached to the furnace shell in a rugged manner. The pouring spout is a groove underneath the door, which enables the molten material to be poured without opening the door, the door itself being opened only during the charging or rabbling time. A false door, consisting of a ribbed cast iron plate, is also provided, so that when the main plug type door is open during the charging or rabbling operations, this false door can be dropped down, shielding the operator from the direct heat of the furnace interior.

The 7-foot diameter furnace is also built in a nose tilting type, and is operated by means of a motor driven screw mechanism at the rear of the furnace (shown in Fig. 4A). In this type of equipment the charging door is placed at the rear and a small opening arranged at the front for pouring the molten metal. This is a type of equipment that is particularly well adapted for pouring directly into molds, and is especially well adapted to casting rolling mill slabs, when used in connection with the rotary casting table shown in the drawing describing this nose tilting type furnace (Fig. 4B), and also in Figure 4C.

Tables 1, 2 and 3 are operating sheets of melting furnaces of this type melting yellow brass scrap, manganese bronze and phosphor bronze.

The casting table is adapted for a vertical adjustment of 40 inches for taking care of molds of different heights, and its turning motion is imparted by means of a motor driven vertical pinion engaging a circular rack attached to the movable table, the molds being attached to the top of the table in the usual manner.

Figure 5 is a view of a 50 K.W. rectangular tilting type furnace adapted to hold a maximum of 500 pounds at a time and having a melting rate of 200 pounds per hour.

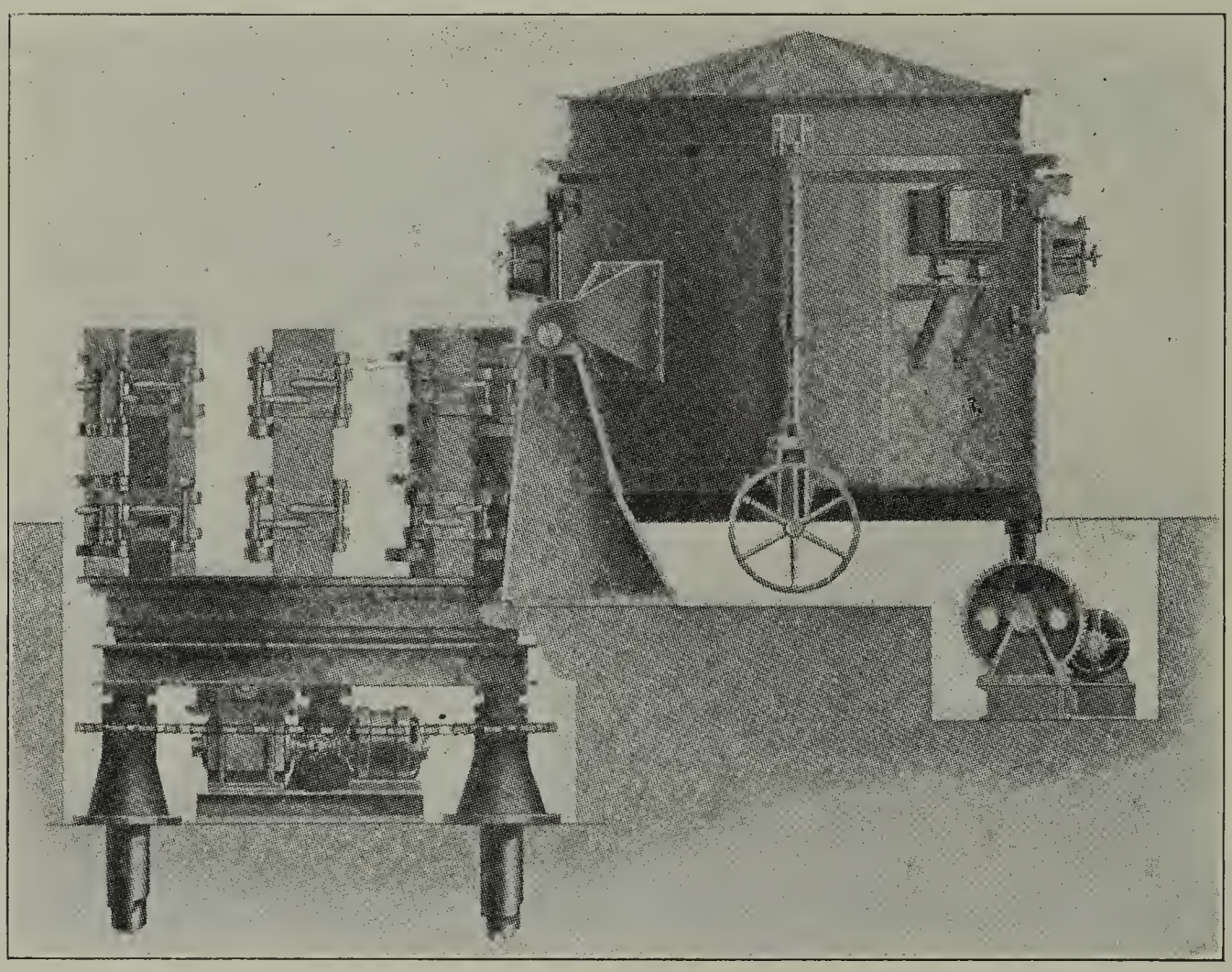

FIG. 4A.—105 K. W. Nose Tilting Type, 7 Feet in Diameter, Motor Operated, with Operated Casting Table.

The furnace is provided with a single resistor trough located directly above the bath, with the electrodes entering at the side. This type furnace is particularly well adapted to the smaller foundries or plants where a wide variety of mixtures are handled in relatively small quantities. The electrical characteristics of this furnace are similar to those of the furnaces just described.

Of the stationary non-tilting furnaces referred to in the preceding part of this paper, the smaller size is of 500 K.W. capacity,

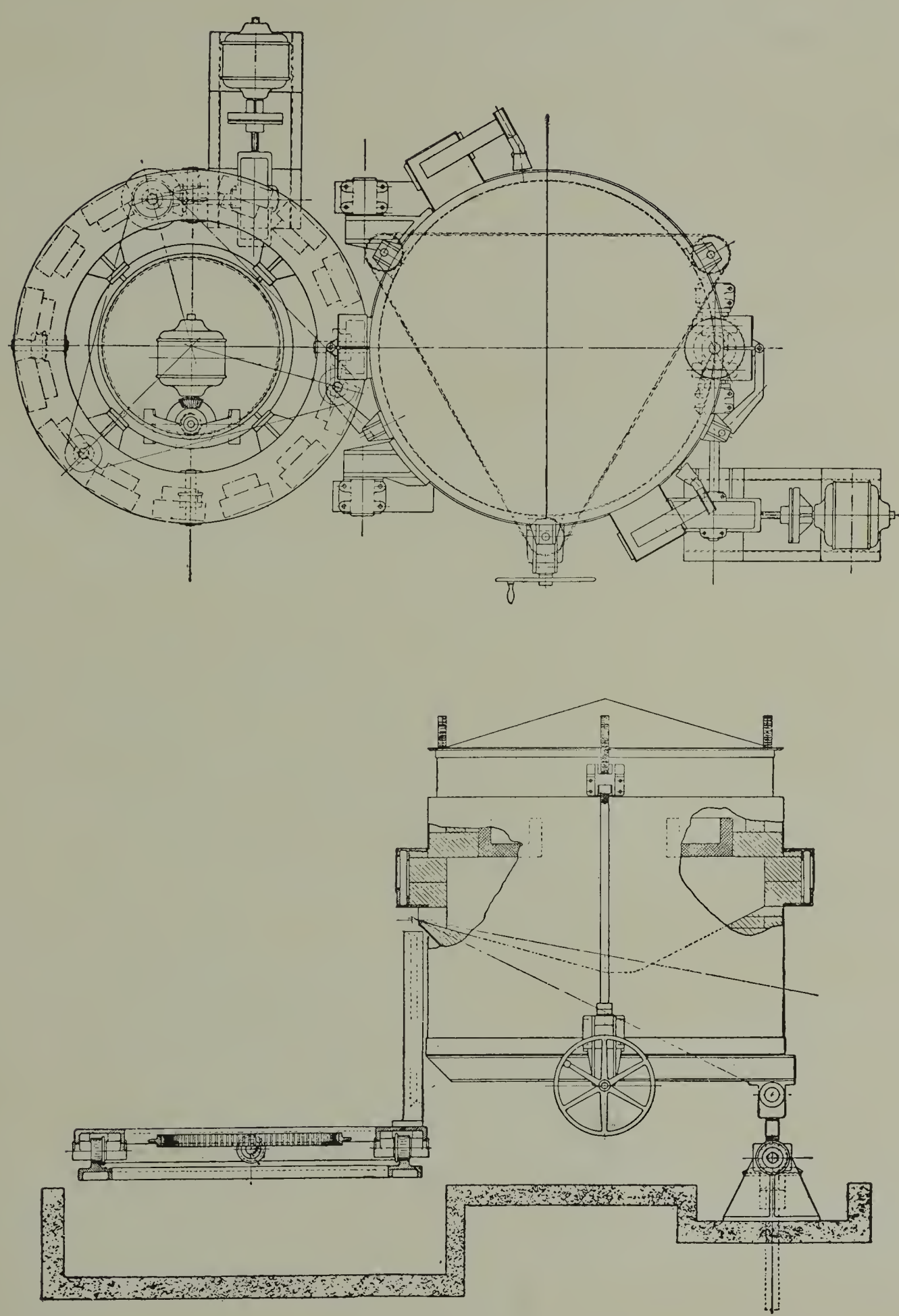

FIG. 4B.—Nose Tilting Type Brass Melting Furnace and Casting Table for Making Brass Slab for Cartridge Cases in Rolling Mills.

and is adapted to hold ten tons of brass or three tons of aluminum. This furnace (shown in Fig. 6) has a resistor trough of the usual type located at each side of the bath, which is supported on the usual fire brick pillars. The doors in this case are located at each end of the furnace and are of the sand sealed type.

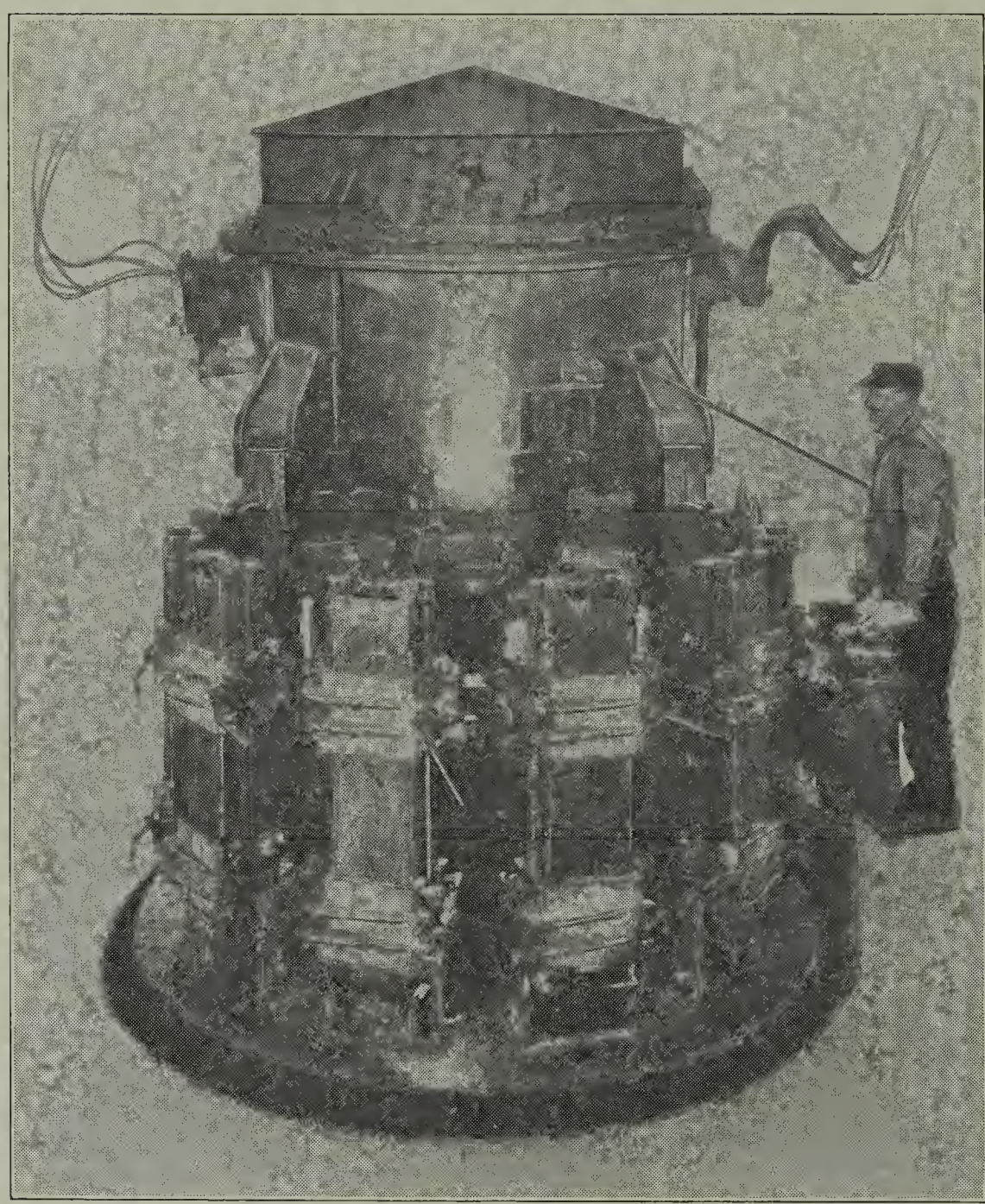

Fig. 4C.—105 K. W. Nose Tilting with Casting Table.

One of these furnaces operating on the remelting of aluminum pig and making aluminum copper alloy is installed at the plant of the U. S. Aluminum Co., Massena, N. Y.

An interesting feature of the use of furnaces of the resistance type described in this paper in connection with aluminum melting

is that for a given quality of castings, a much higher percentage of scrap or remelted metal can be used than is the case when using either iron pots or open flame furnaces.

This is an added advantage over other types offered for the purpose, in addition to the desirable feature of close temperature control, which is essential in aluminum melting, in order to get a high yield of good castings.

A larger size of this rectangular type of furnace is shown in Figure 7, and is an installation of a 1000 K.W. furnace for melting

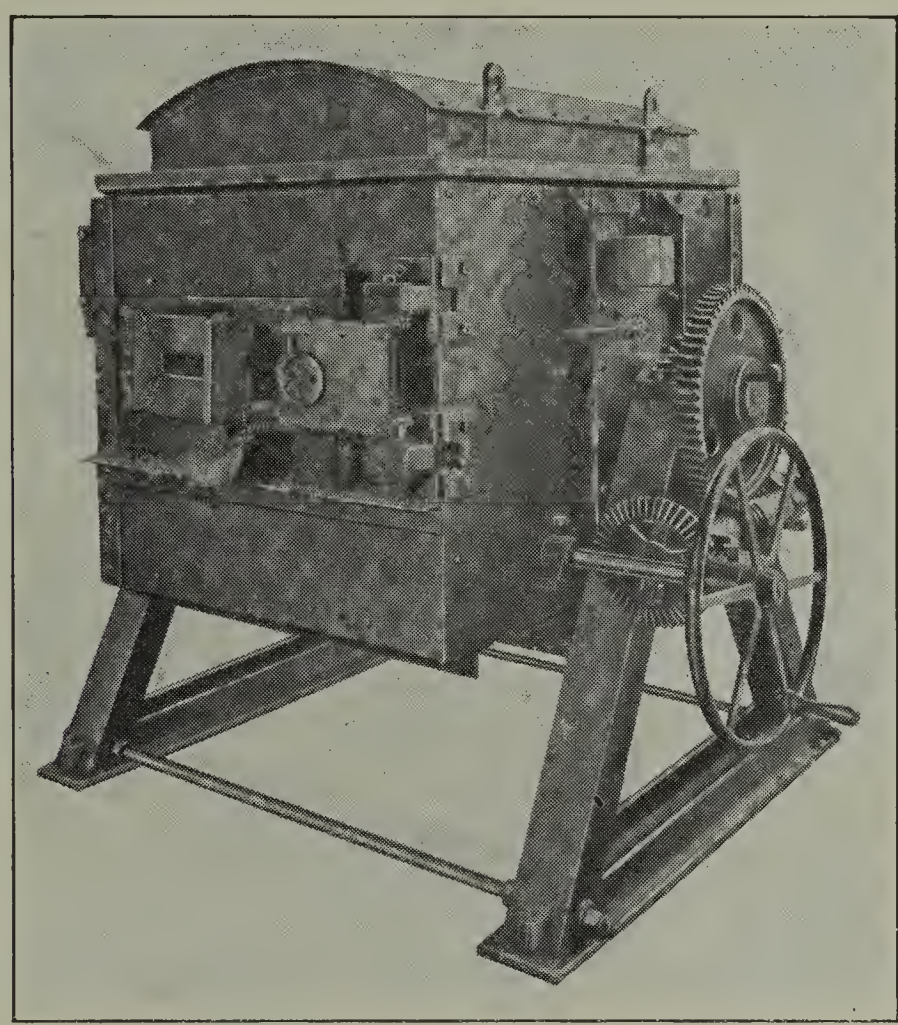

Fig. 5.—Rectangular Tilting Furnace.

zinc cathode at the plant of the Anaconda Copper Mining Co. This furnace has a maximum hearth capacity of 50 tons and a melting rate of 200 tons per day. A comparison of the current consumption and metal losses when operating at various capacities shows that the metal loss in pounds per hour is substantially the same at all capacities and as the capacity approaches the maximum rate of 200 tons, the metal loss drops to below 1 per cent.

The furnaces described in this paper are the result of years of

experience, first in the development and operation of furnaces for the annealing and heat treating of steel, and later a wide experience over the last several years in furnaces built especially for the melting of brass and other non-ferrous alloys, which it is believed will find a wide application throughout the non-ferrous industry, not only in brass foundries and rolling mills, but also in melting and refining smelters. This is particularly true of the furnace de-

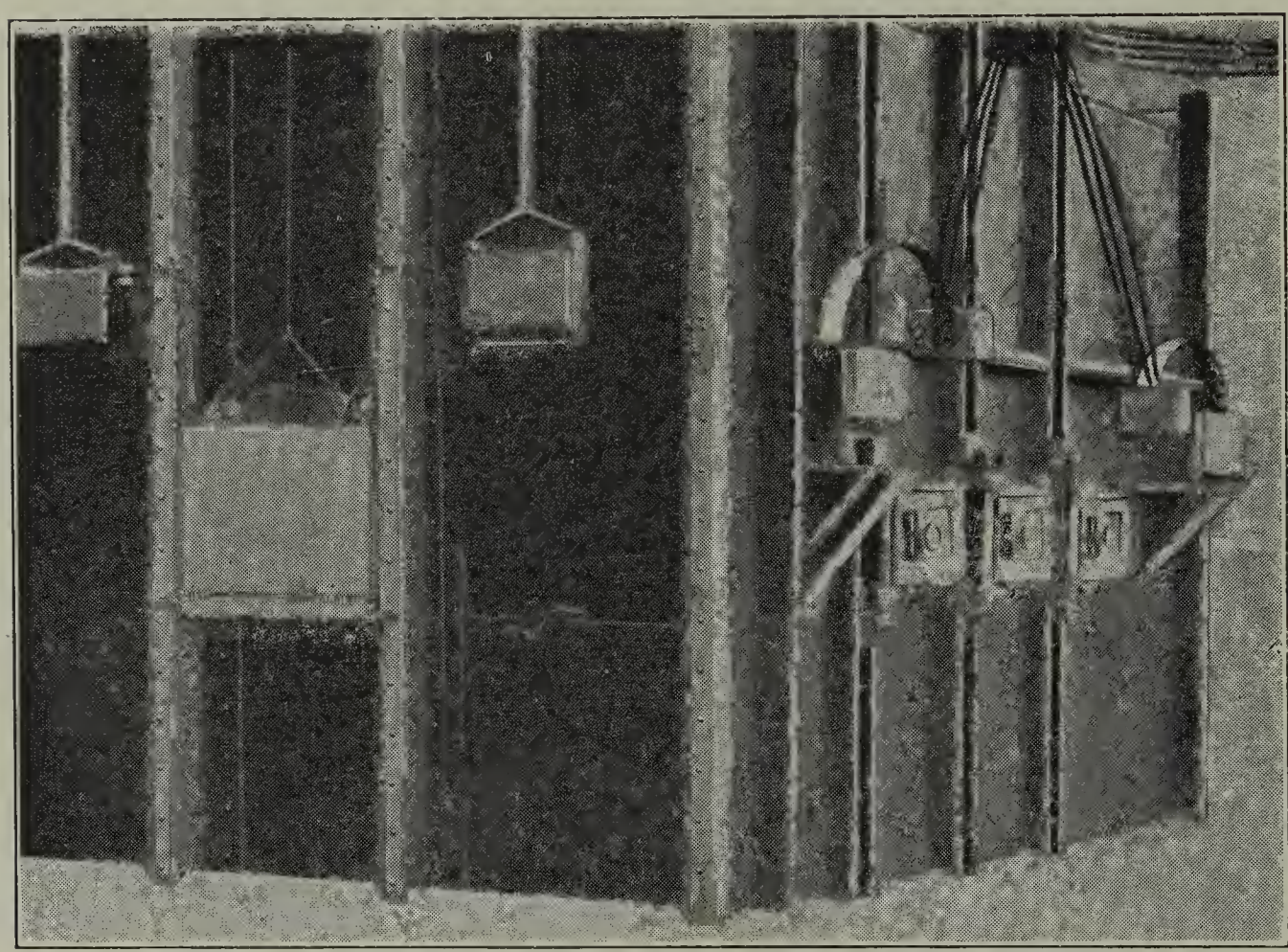

Fig. 6.—500 K. W. Tapping Type. Hearth Capacity 3 Tons, Remelting Aluminum Pig at The United States Aluminum Company, Massena, N. Y.

scribed for melting cathode zinc, which it is believed will find a wide application in the melting of cathode copper, which latter operation has been accomplished in furnaces of this type without the usual blowing and poling necessary in refining; and producing copper wire bar or ingot of substantially the same analysis as the copper cathode, the finished bar or billet, having only that amount of sulphur contained on the cathode as charged and coming from the electrolyte.

As an example of what may be accomplished and of the com-

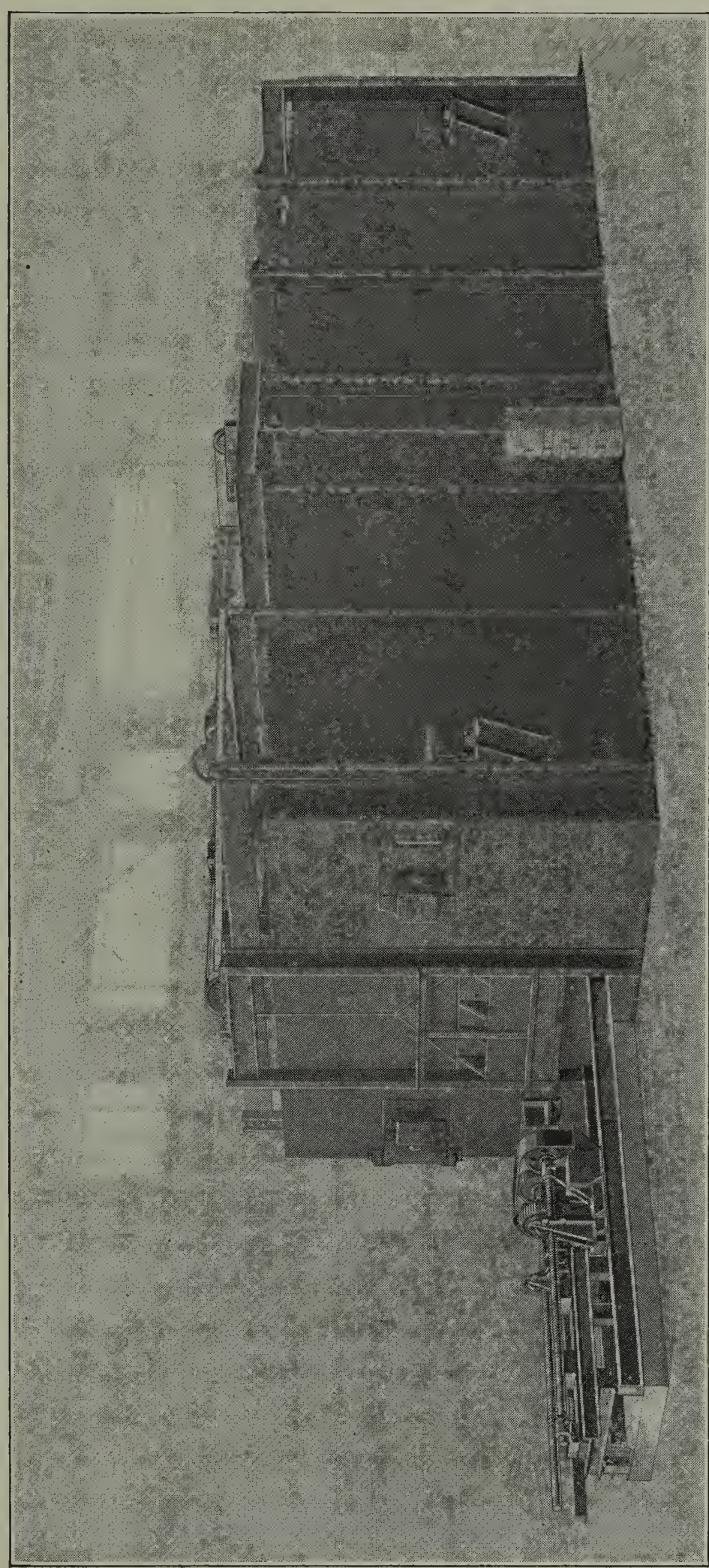

FIG. 7.—1000 K. W. Furnace for Melting Zinc Cathodes. Anaconda Copper Mining Co., Butte, Montana.

parative amounts of sulphur contained on the edges of the cathode sheets as compared with the center, a quantity of copper cathode was obtained and the edges of the sheet to a depth of about two inches sheared off. This material was melted in one of our standard 105 K.W. furnaces and cast into pig. The analysis of the bars so cast is shown in Table A below, while the results from the melting of the inner part of the sheet are shown in Table B.

TABLE A—ANALYSIS.

99.904 Cu.	.084 O.	.0021 S.	Conductivity 100.1

TABLE B.

99.950 Cu.	.036 O.	.0012 S.	Conductivity 100.8

In the remelting of clean scrap, wire and similar substantially pure copper materials, it is found that this clean scrap can be remelted without any deterioration in the quality whatever, the furnaces of the character described in this paper will undoubtedly shortly come into general use for not only the melting of copper cathode, but for the remelting of rolling mill scrap as well.

In the development of these melting furnaces constant attention has been paid to such features as were deemed necessary for the production of equipment that could operate over long periods of time without shut down, having good electrical characteristics convenient and accurate control of both the metallurgical and thermal characteristics, and which could at all times operate under reasonably high efficiency, but no attempt has been made to sacrifice the qualities of ruggedness of design and reliability of operation to the more consideration of current consumption under test conditions.

TABLE I.

TEST ON BAILY ELECTRIC FURNACE AT ANACONDA COPPER MINING CO., GREAT FALLS, MONT.

January, 1919. 1,000 K.W. Melting Furnace, No. 322.

Date.	No. Heat.	Kind of Material.	Time		Time Lost.	Weight Charged.	Weight Poured.	Dross, Lbs.	Dross Pct.	Roof Temp.	K.W.	Volt-ages.	Meter, Begin End		K.W.H. Used.	K.W.H. per Ton Charged.
			Start	End												
			a.m.	a.m.	hrs.					° C.						
6	1	Zinc cathodes	8	8	5	109,890	93,480	16,410	14.9	500	285	250	No meter		5,400	100
7	2	" "	8	8	8	156,780	146,940	9,840	.06	500	365	330	"		5,850	75
8	3	" "	8	8	8	154,315	140,610	13,705	.08	500	365	330	"		5,800	80
9	4	" "	8	8	4	108,260	96,736	11,524	.106	525	225	230	"		4,320	80
10	5	" "	8	8	4	229,330	212,987	16,343	.07	525	456	290	"		9,120	80
11	6	" "	8	8	4	173,260	161,183	12,077	.06	550	433	290	"		8,660	100
12	7	" "	8	8	4	181,750	171,040	10,710	.05	550	450	295	"		9,000	100
13	8	" "	8	8	4	162,440	149,773	12,667	.07	550	600	400	"		12,000	140
14	9	" "	8	8	6	181,220	171,890	9,330	.05	550	700	425	"		12,000	132
15	10	" "	8	8	8	159,350	143,816	15,534	.09	560	700	425	"		12,000	150
16	11	" "	8	8	4	204,030	190,505	13,525	.06	575	600	400	"		12,000	127
17	12	" "	8	8	3	146,500	137,458	9,042	.06	575	225	230	14	15	3,600	50
18	13	" "	8	8	4	172,790	161,002	11,788	.06	575	360	250	15	17	7,200	83
19	14	" "	8	8	4	161,330	149,652	11,678	.06	575	450	250	17	19½	9,000	112
20	15	" "	8	8	4	274,520	263,385	11,135	.04	525	450	250	19½	22	9,000	65
21	16	" "	8	8	4	212,110	201,103	11,007	.05	575	540	330	22	25	10,800	101
22	17	" "	8	8	11	195,900	187,921	7,979	.04	575	550	350	25	27	7,200	74
23	18	" "	8	8	10	192,500	183,710	8,790	.04	600	600	400	27	30	10,800	112
24	19	" "	8	8	5	302,070	293,956	8,114	.02	650	575	400	30	33	10,800	71
25	20	" "	8	8	8 : 20	252,890	242,470	10,402	.04	650	675	412	33	36	10,800	85
26	21	" "	8	8	4	265,520	258,696	6,824	.025	675	540	400	36	39	10,800	81
27	22	" "	8	8	4	279,240	270,369	8,871	.03	675	540	400	39	42	10,800	77
28	23	" "	8	8	4	255,430	247,119	8,311	.03	675	450	250	42	44½	9,000	70
29	24	" "	8	8	4	257,410	250,163	7,247	.028	675	450	250	44½	47	9,000	70
30	25	" "	8	8	4	323,500	320,746	2,754	.008	700	650	440	47	50⅗	12,960	80

TABLE II.

TEST ON BAILY ELECTRIC FURNACE AT BUICK MOTOR CO., FLINT, MICH.
Summary of Test for 6 Day Run on Furnace No. 317.

Date.	Kind of Material.	Weight Charged.	Weight Poured.	Loss, Lbs.	Average Pct.	Average Roof Temp.	Average Bath Temp.	Average K.W.	Average Vt.	K.W.H. per Ton Used Charged Remarks: Less Heating Approx. Up Current K.W.H. Used to Heat Up Before Charging.		
5123	Phos. bronze	5755½	5704½	51	.88%	2300	1960	100	99	894	310	290
24	Phos. bronze	6033	5991½	41½	.68%	2360	2000	102	100	907	306	290
27	Phos. bron e	6020	6003	17	.28%	2340	1980	100	98	887	294	290
28	Phos. bronze	6041	6000	41	.67%	2340	1980	98	99	960	316	290
29	Phos. bronze	7216	7279	63	Gain	2360	2000	100	100	931	258	290
31	Phos. bronze	4708	4708	0	....	2360	2000	98	100	897	380	290

Total metal charged for 6 day run, 35,773½ lbs.
Total metal poured for 6 day run, 35,686 lbs.
Total metal loss for 6 day run, 87½ lbs.
Per cent. loss for 6 day run, .24%
Total K.W.H. used for 6 day run, 5476 Less heating up current.
K.W.H. per ton charged for 6 day run, 306 Less heating up current.
Approximate K.W.H. to heat up before charging for 6 day run, 1740.
Approximate K.W.H. per ton charge to heat up before charging for 6 day run, 96
Total K.W.H. used for 6 day run, 7216 Inc. approx. K.W.H. heating up current.
K.W.H. per ton charged for 6 day run, 402 Inc. approx. K.W.H. heating up current.
Max. roof temp. attained for 6 day run, 2360° F.
Max. bath temp. attained, for 6 day run. 2000° F.

NOTE.—Current used to dry out furnace and bake trough not included in this summary first day's run not included as there is a certain amount of metal absorbed the first day by a new hearth which would not occur in further operation.

Test made by G. C. Paxton—Summary by G. C. Paxton, June 6, 1918.

TABLE III.

CONDENSED RESULTS OF TESTS ON MELTING FURNACE AT LUMEN HEATING COMPANY.

Time.	Heat.	Metal Charged.		Time of Heating.		K.W.H. Consumed.	K.W.H. per 2000 lbs. Charged.
		Kind.	Weight.	Hrs.	Min.		
4-30-17	1	Copper, Cu 348	1513	4	10	345.8	455
4-30-17	2	Tin, 45 Phos, 8 353	401	1	8	82.47	410
5- 1-17	1	Phos, 40 8 352	401	1	17	99.7	496
5- 1-17	2	Phos, 40 8 352	400	1	10	101.1	500
5- 1-17	3	Phos, 40 8 352	400		55	77.5	386
5- 1-17	4	Phos, 40 8 352	400		55	93.8	470
5- 1-17	5	Phos, 40 8 352	400	1	05	82.1	410
5- 1-17	6	Phos, 40 8	400	1	00	88.2	440
5- 8-17	1	Scrap Radiator tubes	671	1	10	124.1	370
5- 8-17	2	Scrap brass	783	1	00	118	300
5- 8-17	3	Copper 72% Zinc 28	816	1	32	159.55	395
5- 8-17	4	Copper 72% Zinc 28	816	1	15	129	313
5- 8-17	5	Copper 72% Zinc 28	816	1	12	142	350
5- 8-17	1	Copper 70% Zinc 30%	816	1	12	101	247
5- 9-17	2	Copper 70% Zinc 30%	816	1	19	104.7	256
5- 9-17	3	Copper 70% Zinc 30%	816	1	20	124.6	306
5- 9-17	4	Brass boring	610	1	52	142.8	365
5- 9-17	5	Brass boring	778	3	03	284.5	935

AJAX-WYATT ELECTRIC FURNACE.

By G. H. CLAMER

Read at the Boston Meeting, June 18, 1919.

THE writer presented before the American Institute of Metals, at its meeting in Boston in 1917, a description of the Ajax-Wyatt Electric Furnace. This furnace is of the closed-channel induction type, having a bath of liquid metal above the channel that produces a hydraulic head and thus avoids the breaking of the metallic circuit due to "pinch effect."

I do not wish to repeat what was given in the paper referred to, other than to review briefly the various types of induction furnaces which have been developed and their relationship to the Ajax-Wyatt Furnace.

The first induction furnace was invented by Edwin Colby of Newark, N. J. This was a simple ring type of furnace in which the secondary consisted of a single turn of molten metal about a magnetic circuit. In the Colby type of furnace, the primary coil was placed outside of the secondary circuit. Colby was in the platinum business and his desire was to create a furnace in which platinum could be melted in a noncarbonaceous atmosphere. Platinum, when melting in contact with carbon, absorbs that element to some degree and makes it difficult to work. Colby did not succeed commercially in accomplishing that which he set out to do, but he did give to the world a type of electric furnace which has been developed into one of great usefulness and importance. From a theoretical standpoint this type of furnace is of the highest efficiency, and is one in which the charge of liquid metal is under perfect control. In the induction furnace the heat is generated within the metal itself and the current consumption is absolutely steady.

Deferranti, in England, patented a similar induction furnace approximately at the same time as Colby. He also placed the primary coil outside of the secondary; the magnetic leakage was

therefore very great and the power factor very low. Both Colby and Deferranti no doubt were afraid to place the primary within the secondary circuit because they had not worked out a proper means for protecting the primary coil from the effects of heat generated in the molten metal.

Kjellin a few years later patented a furnace in which the primary coil was placed within the secondary. Magnetic leakage was thereby greatly reduced and the power factor, on furnaces in which the secondary ring was of relatively small diameter, could be maintained quite high. With increasing diameter of the secondary ring, the power factor becomes correspondingly low. It was this invention of Kjellin which put the induction furnace in position to become a commercial competitor of the arc type of furnace for steel melting.

Because of the effect of the size of the secondary ring on the power factor, the Kjellin type of furnace could be applied commercially only in relatively small sizes, if currents having normal frequency were used. Fairly large furnaces have been made by using current of low frequency and in one form of furnace of this type, frequency as low as five cycles has been used.

In 1907 Colby improved upon the Kjellin furnace by making the primary coil in the form of a water-cooled conductor. A small furnace of this kind, which poured a charge of ninety pounds of steel, was tried out experimentally at Henry Disston & Sons Works in Philadelphia.

A great improvement was made upon the Kjellin furnace and embodied in the now well-known Röchling-Rodenhauser furnace. A two-phase furnace of this type is nothing more than two Kjellin furnaces placed together and in which the working hearth forms a section of the secondary circuit of each of the phases. It is possible, by restricting the cross-section in the channel portion of the secondary loop, to maintain a fairly high resistance and to cut down the magnetic leakage. By reason of the common hearth produced by this construction, fair-sized working space is provided. Magnetic leakage is further cut down by placing an auxiliary coil in such position that current of relatively high voltage is induced therein. This current is led to pole pieces placed at the opposite sides of the hearth and is conducted by means of a conductor of the second class through the bath. The resistance set up in this conductor of the second class provides additional heat

units to the bath. In a furnace of three-phase construction the same general construction is used and in this case a still larger hearth area is possible.

A number of other inventions have been made in the open-channel type of induction furnace, but these embody only details of construction, and do not represent any divergence from the original principle of operation as described by Colby. Some of them embody features for cutting down the magnetic leakage similar to the method used in the Röchling-Rodenhauser furnace.

Schneider, president of the Creusot Works of France, was the first to use the closed secondary with a bath of liquid metal above it. Schneider evidently did not understand the action of "pinch effect" and he describes the circulation in his furnace as resulting entirely from thermal effect. A certain "pinch effect" must of necessity have been present and this intensified the rate of circulation.

About 1909 Dr. Carl Hering observed the "pinch effect" in a molten circuit carrying current of high current density. His observations were recited to Dr. Edwin F. Northrup, who explained the phenomenon and worked out the mathematics in connection therewith. With an understanding of the magnitude of this force, Dr. Hering applied it in the construction of an electric furnace. In the furnace, as originally constructed by him, current was led by electrodes to columns of liquid metal retained within a tubular wall. These columns of metal were of relatively small cross-section and carried currents of high density. The circuit was completed by the metal bath. Heat was developed in the metal in these channels, known as resistors, and energetic circulation ensued by reason of the "pinch force." Appreciating that this force could also be used in an electrodeless furnace, namely, one of the induction type, Dr. Hering in his patent added claims also covering this form.

While carrying on development work with the Hering electrode type of furnace, Wyatt constructed an induction furnace, which for circulation depends not only upon "pinch effect," but also upon motor and thermal effect. Motor effect was added by the simple means of forming an acute angle in the secondary channel. This acute angle, being formed at the extreme bottom of the channel, produces very energetic circulation at the root or bottom. As the channel is placed in a vertical position, the circulation is still

further assisted by thermal effect, namely, differences in density resulting from differences of temperature.

Certain inherent difficulties became apparent in the Hering electrode type of furnace as the development work progressed. Briefly, these are as follows:

1.—Melting of electrodes back to the point where further melting was prevented only by the water cooling. Many means for preventing this were tried but without success.

2.—Because of the shortness of the solid portion of the electrode, hence the proximity of molten metal to the water, an element of danger was encountered and high heat losses resulted.

3.—Because of the necessity of embedding electrodes in the refractory material, cracking of the refractory resulted due to differences in the coefficient of expansion of the electrode as compared with the refractory material. Liquid metal flowed in these cracks and resulted in short circuiting.

As the induction furnace uses no electrodes, these difficulties are entirely overcome.

Plate I illustrates two views of the furnace jacket used in the Ajax-Wyatt furnace, with dotted lines thereon to indicate the secondary circuit and the direction of the circulation.

In Figs. 1 and 2 is shown one form of the Ajax-Wyatt electric furnace, having in general a body (1) and channel portion (2) connected therewith by a transformer (3). These with the closure for the body are adapted to be rotated about trunnions (4) in any suitable bearings by means of worm wheel (5). The means for securing support and rotation are so well known that I have considered their illustration to be unnecessary. In this particular form, the furnace body, adapted to receive a pool of molten metal and melt the pieces of metal down into it, is made up of an outer jacket (6) lined at (7) and carrying a pouring spout (8). The upper portion of the body is partly closed by an annular tile (9) held in a shell (10) and having a conical opening in the annulus in which fits a plug (11) carried by a cover (12) and hinged at (13). The shell (10) is secured to the jacket (6) by means of ears (14) and bolts (15). In this construction, it is preferred not to connect the casing (16) within which the lower part of the channel is formed directly with the body of the furnace, but to

interpose the transformer between and form part of the channel actually within the transformer as distinguished from having the channel member merely pass through a gap in the transformer. In this way, the shell type of the transformer shown is built into the unit and forms part of the mechanical protection and frame of the complete furnace, reducing the metal parts, avoiding interruption of the magnetic circuit of the transformer, in order that it may be put in place and reducing heat losses. The transformer is con-

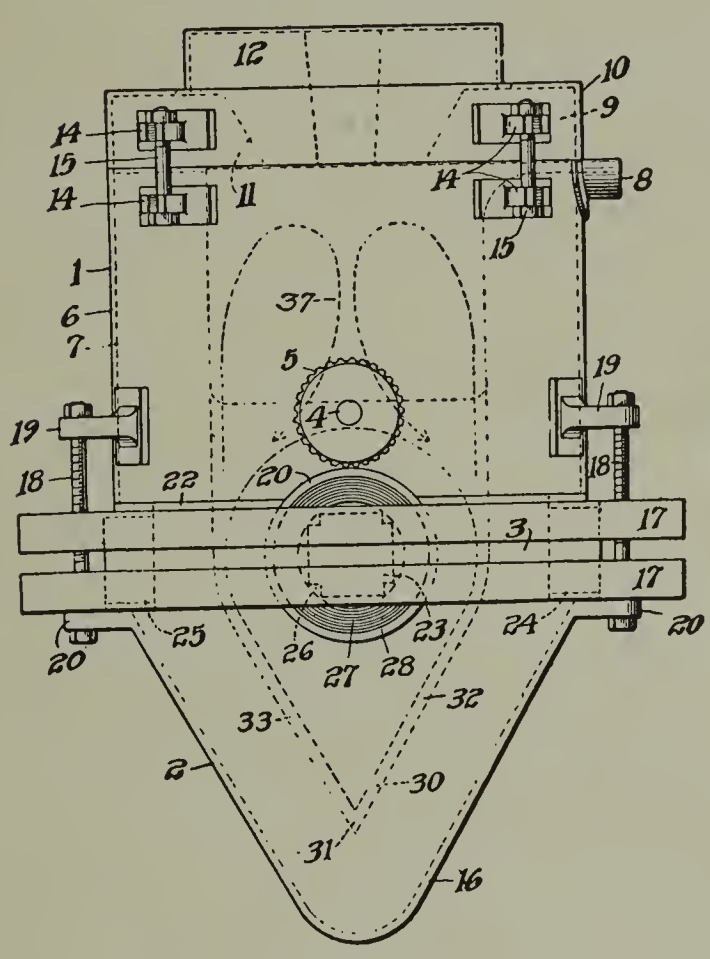

FIG. 1.

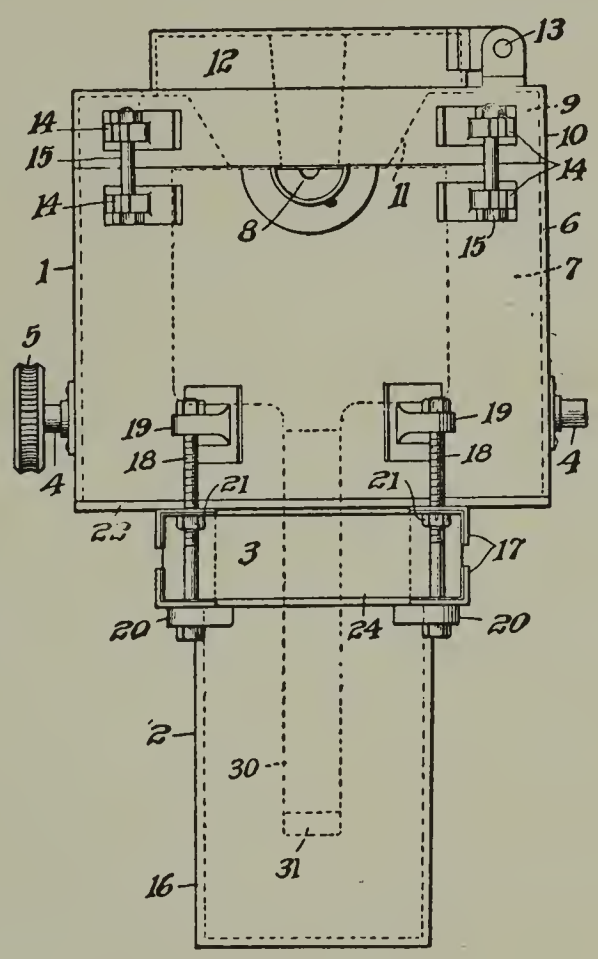

FIG. 2.

PLATE I.—Drawings from Patent Specification showing Internal Construction of Furnace and Direction of the Flow of Metal.

veniently connected to the other parts by the use of angle irons (17) at the top and bottom. Bolts (18) pass through these and through ears (19) upon the jacket and flanges (20) of the casing clamping the body, transformer and casing (16) firmly together. The bolts are secured by nuts (21) and corresponding nuts separately engage the under sides of the upper angle irons. A pair of brass spacing plates is shown at 22.

The transformer shown is of a single-phase shell type. Its laminated magnetic circuit has a central leg (23) and end legs (24

and 25). To accommodate a close circular winding, the edges of the central leg are cut, as shown, and the winding is put on in the form of a series of layers of parallel circular bands forming a circular primary winding. In the structure used, the primary winding (27) was formed from a flat strip of conductor wrapped with asbestos insulating tape and applied in rings interrupted at the points of cross connection with adjoining rings and also cross connected from one layer to the next at the ends of the rings adjoining layers. The casing (16) is a casting designed to engage the angle irons on opposite edges of the lower part of the transformer and to engage the edge of the primary winding. In lining the furnace frame thus formed, a two-part pattern is inserted having the shape of the channel and pool and having a division line between the parts at some point as 28, so that the lower part of the cementitious lining used can be placed and rammed before the upper part of the pattern can be inserted and the lower part of the pattern is put in place. Plastic material is then rammed about the form inside and out, completing the lining within the casing, transformer, and body of the furnace and filling the entire space about the primary winding except the portion occupied by the pattern; the pattern, which is so made that its expansion does not crack the lining, is melted out by the current. A clay and asbestos insulating compound is used for linings—this is subsequently dried out gradually.

The channel (30) is flattened in cross section, preferably of rectangular or approximately rectangular shape and with the longer dimension of rectangle parallel with the axis of the transformer winding. The channel length is formed with an acute angle at the turn at (31) outside of the furnace and in the turn at the pool acute angles are avoided, the contour being rounded between the connections with the pool or at least obtusely angled where the connections are made with the furnace. In the form of Figs. 1 and 2, the channel meets the pool in a generally vertical direction, and on opposite sides at the outer edges of the pool, thus securing a maximum effect for the stirring action produced within the channel.

When electric currents traverse fluid conductors (such as molten fluid in the channel parts 32 and 33), and flow in opposite directions, electro-dynamic forces are set up in the conductors in directions perpendicular to the lengths of the conductors, tending to separate the conductors. These forces vary directly as the product

of the current flowing in the two conductors (as the square of the current where the same current flows in each) and inversely as the distance between the parts of the fluid affected. Where these conductors are not parallel, the electro-dynamic forces vary in magni-

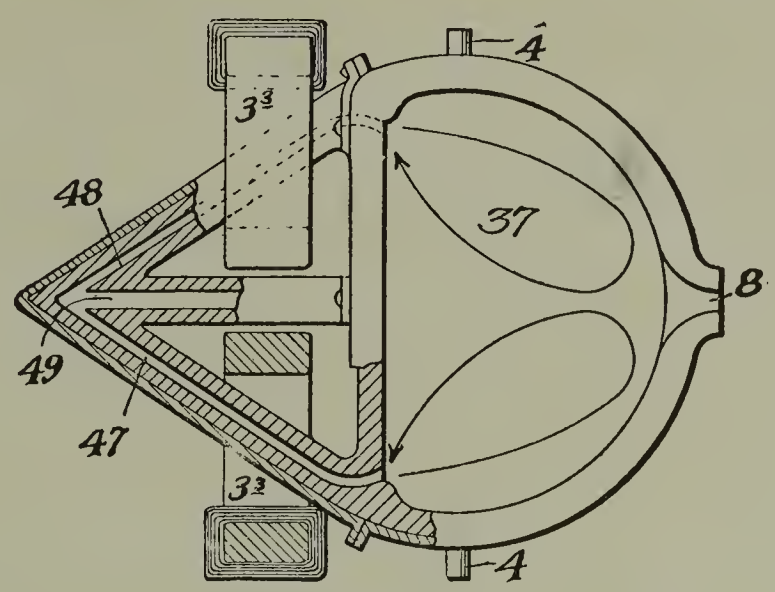

PLATE II.—Drawing from Patent Specification showing One Arrangement for Two-Phase Furnace.

tude from one point to another along the lengths of the conductors, because of the differing distances separating them at these points and cause correspondingly varied hydro-dynamic forces tending to produce motion of the fluid parallel to the lengths of the con-

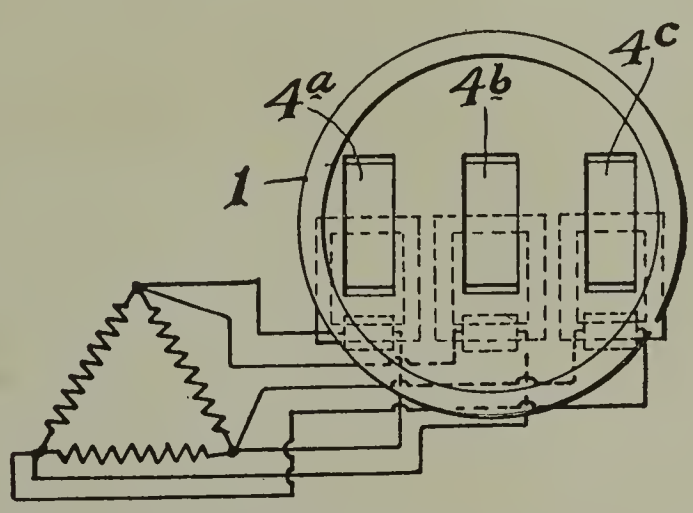

PLATE III.—Drawing from Patent Specification showing One Arrangement for Three-Phase Furnace.

ductors. The application of motor effect causes motion of the fluid and hence circulation, if the fluid be free to flow. The motor effect, causing this circulation, may be intensified by bringing the conductors together into an angle and becomes most effective where the angle is acute, increasing within reasonable limits with the

acuteness of the angle. Though Joule effect and some pinch effect is also present, the hydro-dynamic pressure due to electro-dynamic motor effect is the dominant force in the Ajax-Wyatt furnace, which not only depends generally upon this pressure for circulation of

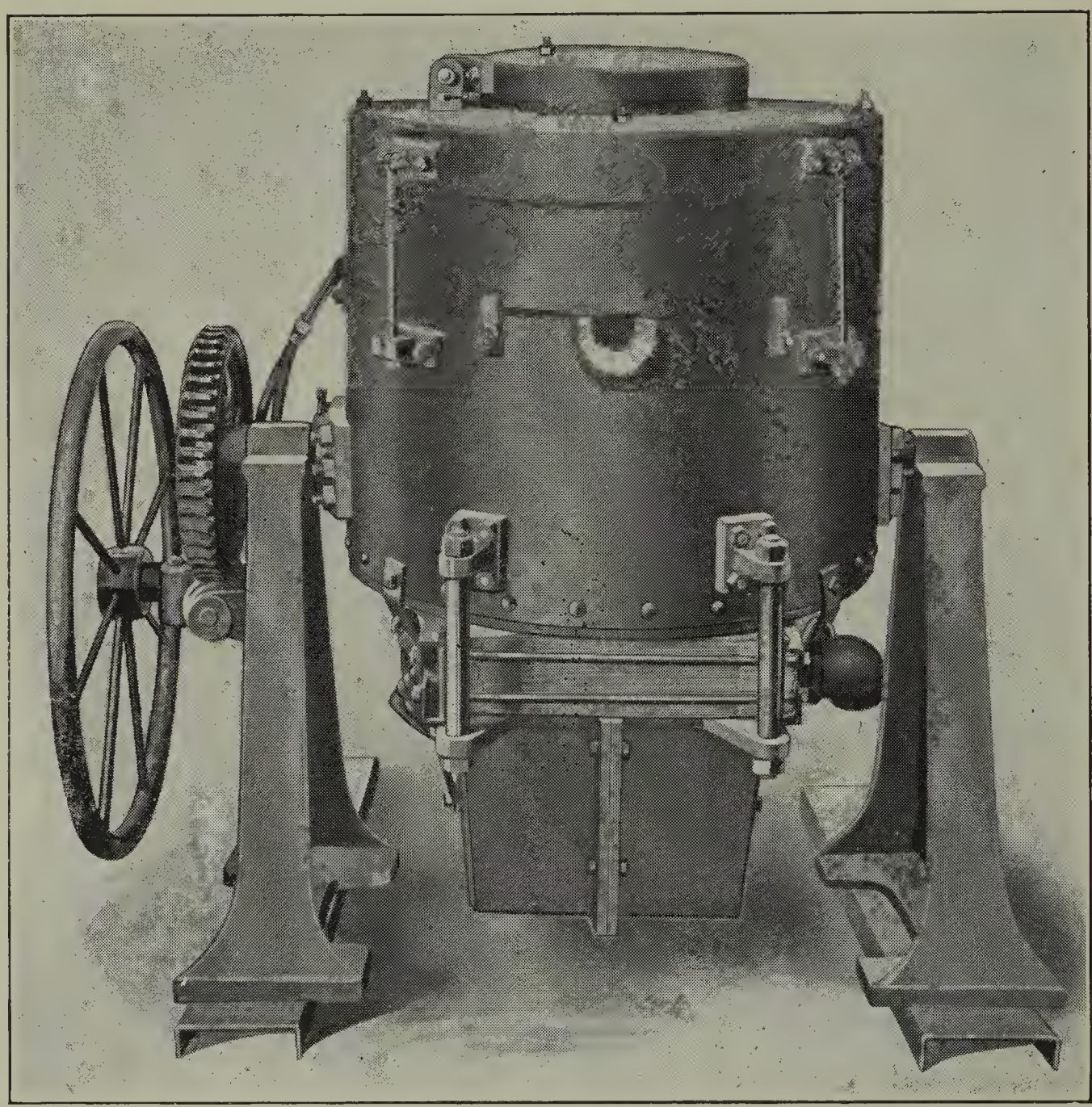

PLATE IV.—30 K. W. Ajax-Wyatt Electric Furnace with Tilting Mechanism for Pouring Furance Charge having a Central Trunnion as a Center of Oscillation.

the heated metal, but gets great advantage from the intensity of the pressure in the angle where overheating would otherwise take place.

The development of the Ajax-Wyatt furnace in single-phase form, having power factor of about 70 per cent, is limited to approximately 80 KW. for brass melting and 100 KW. for steel melting. This limitation is established by the size of the secondary

loop. It can, however, be developed for two and three-phase operation. Phase II shows diagrammatically one two-phase form.

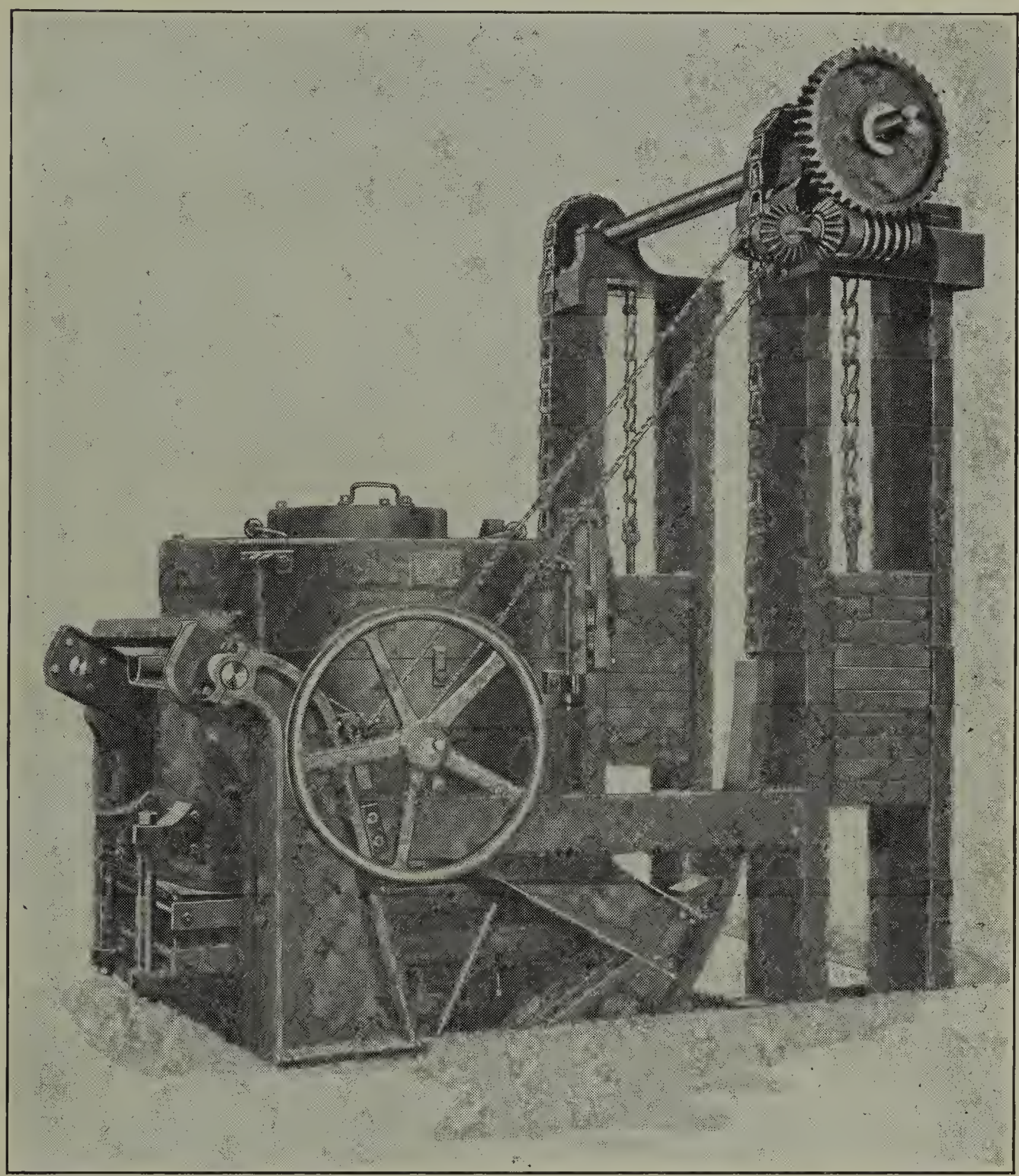

Plate V.—60 K. W. Ajax-Wyatt Electric Furnace with Tilting Mechanism for Pouring the Furnace Charge, having the Lip as a Center of Oscillation.
Normal Position

It is, therefore, possible to produce a brass furnace of two-phase construction of 160 KW. capacity, and for steel 200 KW. capacity. The furnace can also be constructed for three-phase operation, as indicated diagrammatically on Plate III. The maximum capacity of

such furnace for brass being 240 KW. and for steel 300 KW. Work on the construction of two- and three-phase type of furnaces

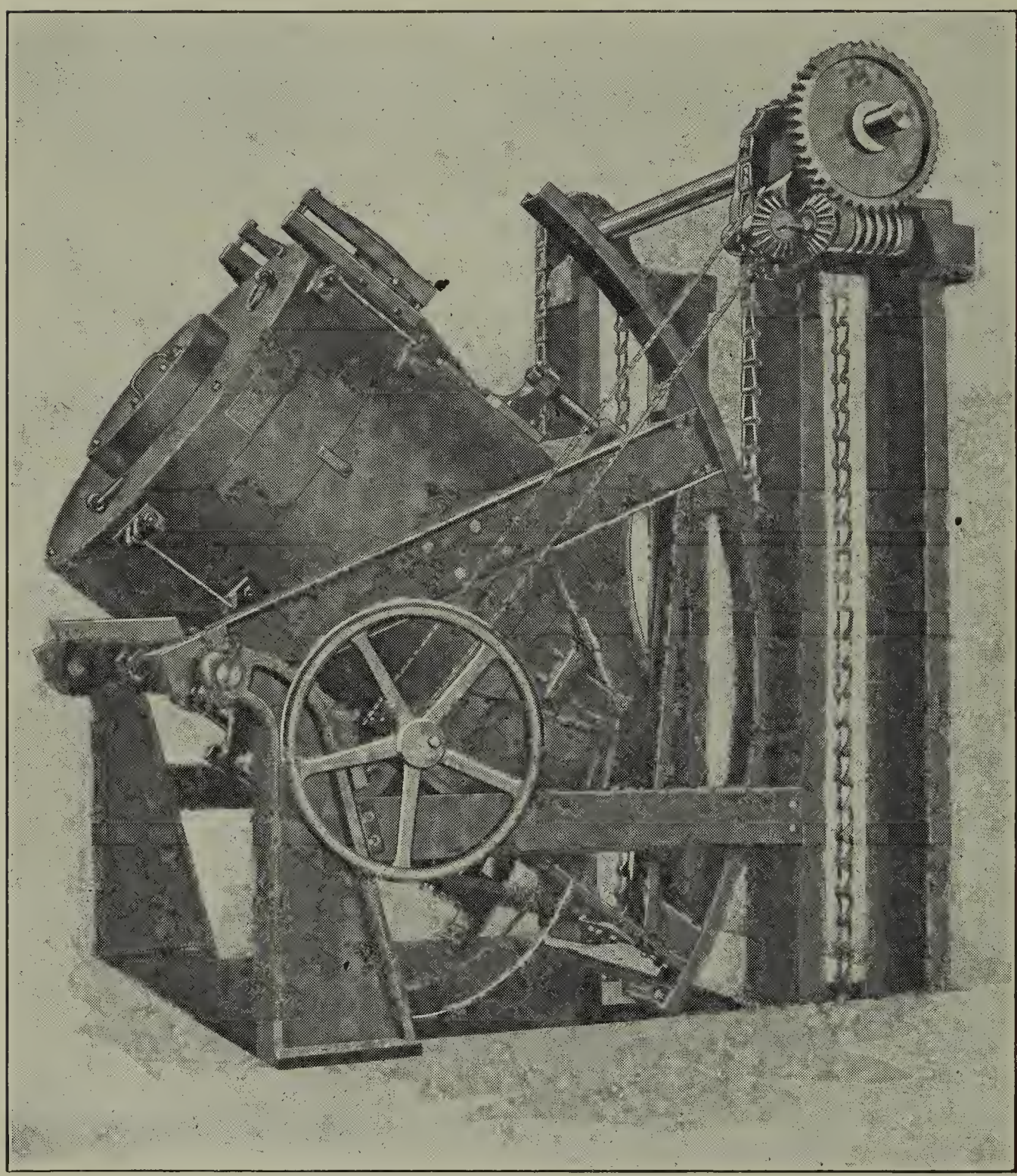

PLATE VI.—60 K. W. Ajax-Wyatt Electric Furnace with Tilting Mechanism for Pouring the Furnace Charge, having the Lip as a Center of Oscillation.
Casting Position

is about to be undertaken. Work will also be undertaken for melting ferromanganese and steel.

Plate IV shows one of the commercial forms of single-phase furnace using a central trunnion. Plate V shows a counter-

weighted type of furnace made to cast upon a trunnion in line with the lip. This furnace is suitable for direct casting into molds of small cross-section. The Ajax-Wyatt furnace has thus far only been recommended and marketed for yellow brass melting. In this field it has been in very successful use for more than two years. Many million pounds of brass have been melted in them and cast into ingots, extrusion billets, flat metal slabs and tube blanks. All manner of stock has been melted in them from solid metal to sawings and washings. The average melting rate is from 8 to 11 pounds of 2-1 yellow brass per kilowatt hour, depending on the capacity of the furnace and the nature of the charge.

The average life of the linings is in excess of 250,000 pounds. Some linings have not required replacement until well over a million pounds have been melted. The metal loss is of course largely dependent upon the nature of the charge, but on clean solid metal averages below one-half of 1 per cent.

The furnace requires no particular skill in operating. Intelligent unskilled labor is used entirely for this purpose.

Development work thus far has been concentrated upon the perfection of the single-phase furnace for brass melting only, and in sizes of 30 and 60 KW. Standardized manufacturing methods have been worked out for these and attention will now be directed toward further development for other purposes and other sizes, and in the two- and three-phase forms.

THE BOOTH ELECTRIC ROTATING BRASS FURNACE.

By CARL H. BOOTH

Read at the Boston Meeting, June 18, 1919

About five years ago we were associated in the design of several electric furnaces for the production of special chemical compounds. These furnaces were cylindrical in shape and arranged to rotate about a central axis through which the electrodes projected. At the time it was suggested that this type of furnace could be adapted to the melting of non-ferrous metals, but there was no opportunity to carry on such work. An illustration of one of these furnaces is shown in Fig. 1.

In these earlier furnaces a door was provided in the cylindrical surface of the shell and lining, for charging and pouring, but we experienced considerable difficulty in maintaining the lining around this combination spout and door. Further, in pouring the furnace it was troublesome and inconvenient to be obliged to place the ladle between the supports beneath the furnace. Consequently, in designing the present Booth furnace, these have been overcome by placing the door in one end of the furnace, as shown in Figs. 2, 3 and 4, and having a tapping hole in the other end, as shown in Figs. 2 and 3. In this way the cylindrical surface of the lining and shell is unbroken by any opening. This permits the continuous rotation of the furnace, and consequently the absorption of heat by the charge from all parts of the lining, which means no local overheating and uniform wear.

General Description. Holding Capacities.

As a general rule, the quantity of non-ferrous metal melted at one time, or at one heat, is less than the quantities involved in the melting of steel and iron, and, therefore, smaller sizes of furnaces are desirable.

To meet the requirements of the small foundry, as well as the large foundry, and the smelters and refiners, Booth furnaces are built in the following sizes:

Rated Holding Capacity	Maximum Holding Capacity
250 Lbs.	350 Lbs.
500 Lbs.	750 Lbs.
1000 Lbs.	1500 Lbs.
2000 Lbs.	2500 Lbs.
3000 Lbs.	4000 Lbs.

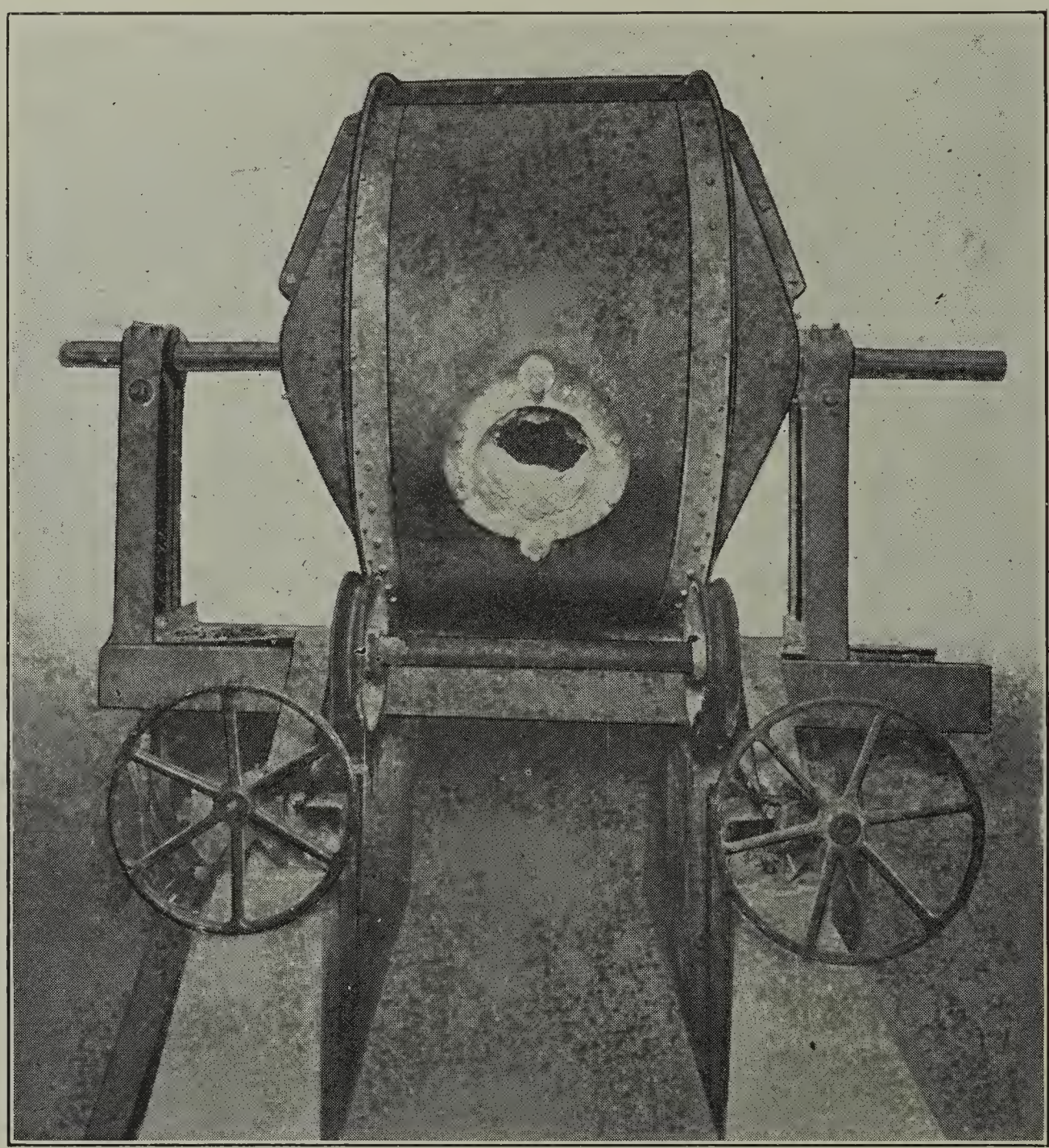

Fig. 1.—Booth Electric Rotating Brass Furnace.

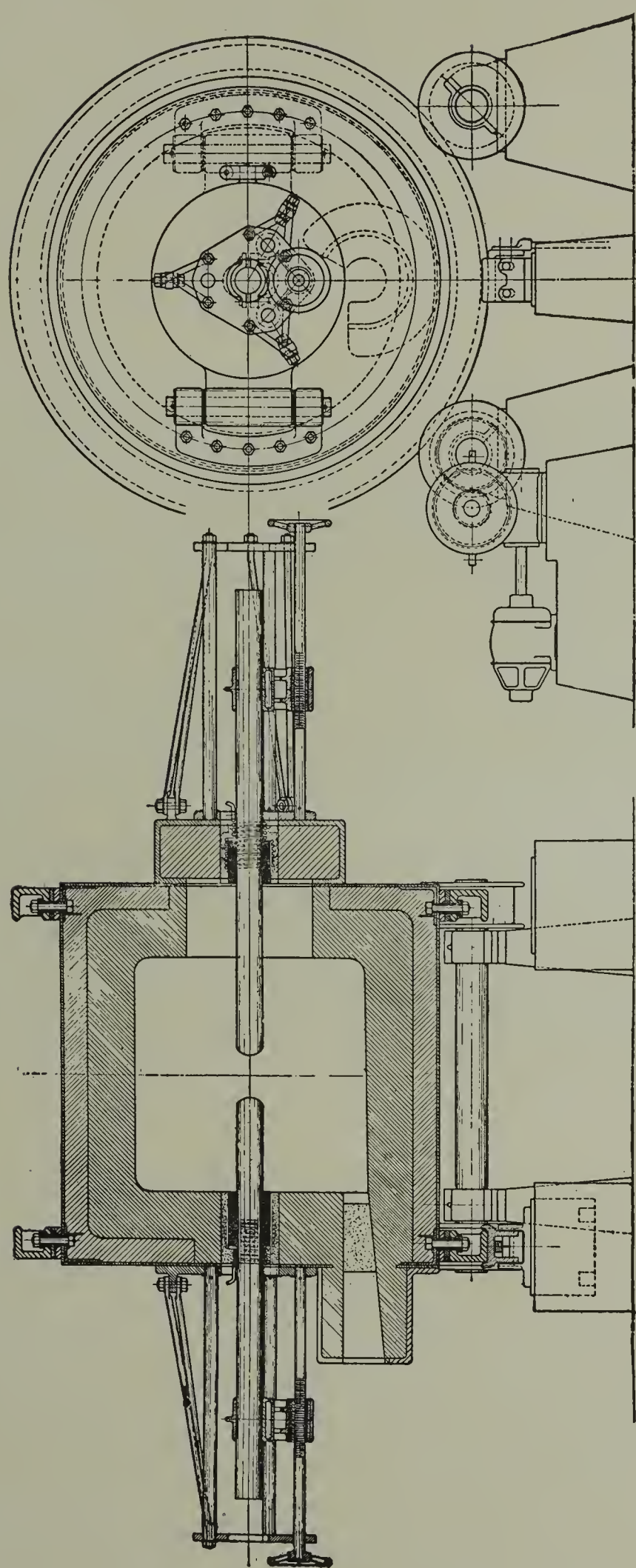

Fig. 2.—Cross-section of Booth Furnace.

There are many small plants where heats of 50 to 350 pounds are required, and the smallest size furnace shown above answers the purpose with great economy, whereas larger furnaces to operate efficiently must produce more metal than is needed. Further, there is also a great disadvantage in trying to pour a ton of brass into small castings and keep the metal hot. We know of a large company having a one-ton electric furnace where it is taking fifty minutes to pour a heat into castings, and they are finding great difficulty in doing so. Further, the great variety of mixtures made

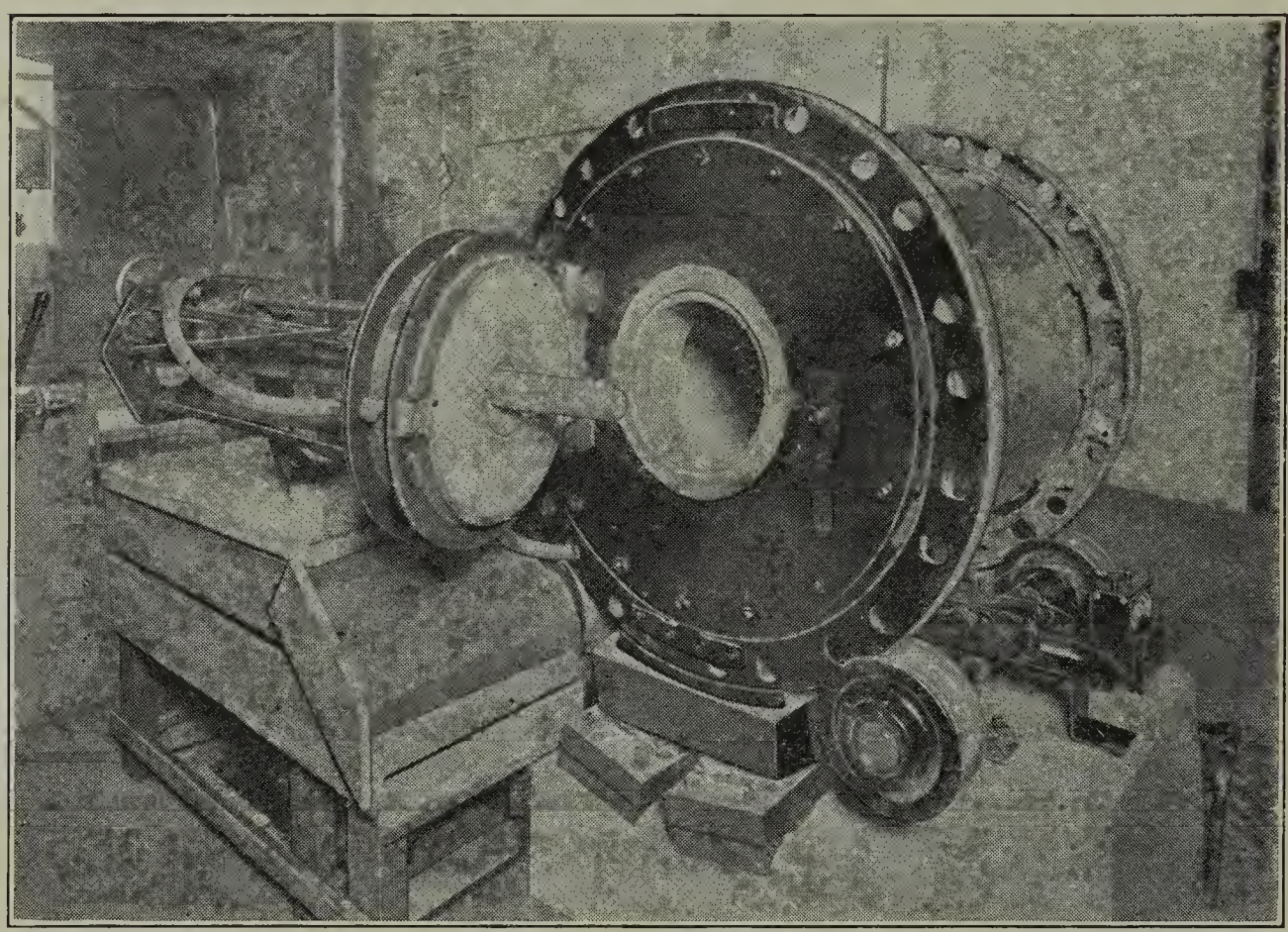

FIG. 3.—Rear View of 250-pound Booth Electric Brass Furnace.

by many small foundries requires a small, efficient unit, from which "short" heats can be taken, producing great flexibility of operation. On the other hand, smelters and refiners frequently require furnaces of relatively large holding capacity, which will turn out a considerable amount of metal per day.

Any one of the above furnaces is guaranteed to melt and bring to pouring temperature a charge of its rated holding capacity in an hour's time, when the furnace is hot.

Mechanical Details.

The illustrations and drawings give a very good idea of the general design of the Booth electric furnace.

Fig. 2 is a cross-section or diagram, illustrating clearly the principle of construction. As will be noted the furnace rotates on rollers, and is carried by two cylindrical tracks. The rollers are driven at the proper speed by a motor, so as to rotate the shell at a speed of two revolutions per minute. No gearing is required

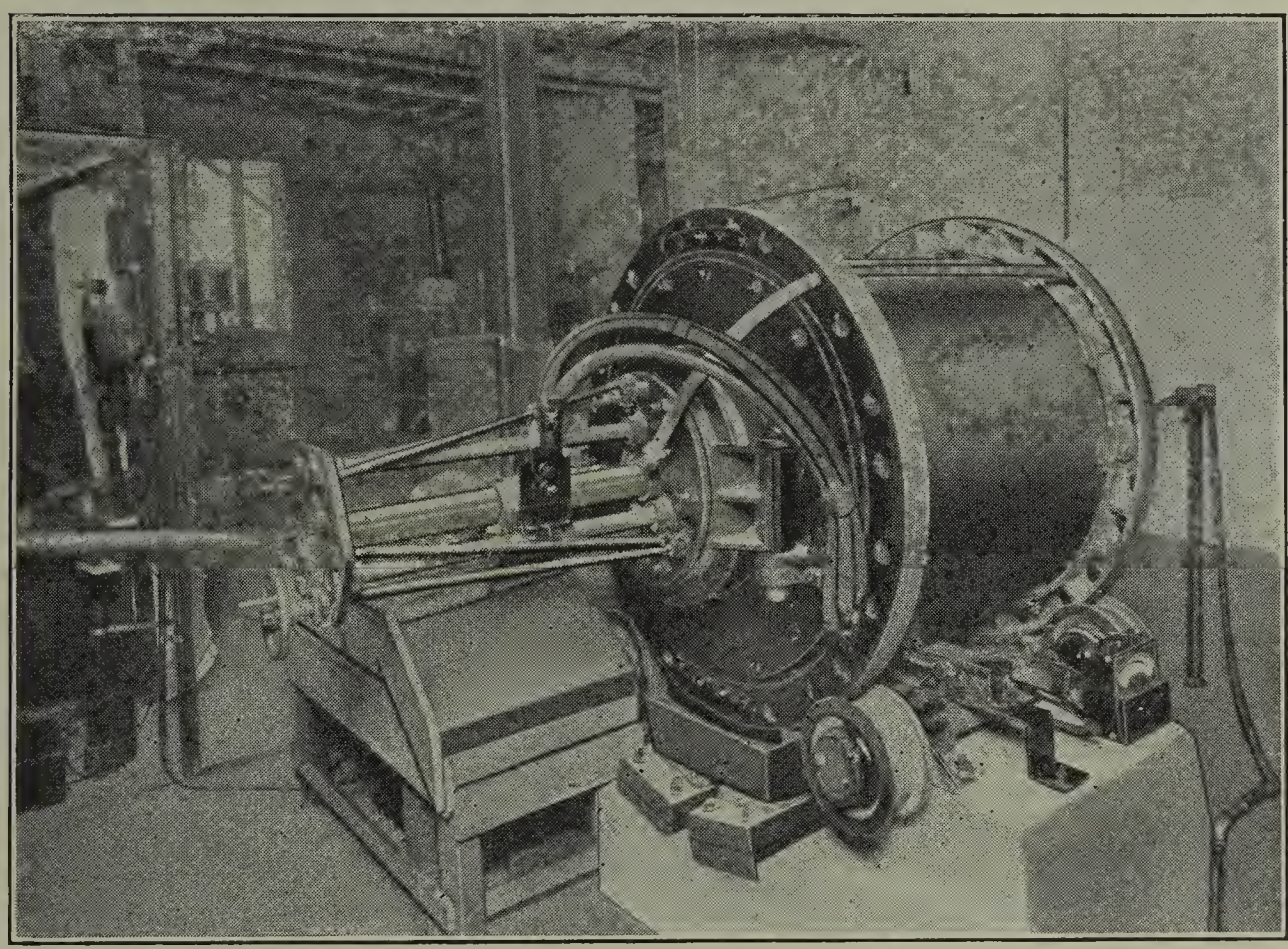

Fig. 4.—Same Furnace as Fig. 3 charged and Ready to Run.

encircling the furnace. The current is carried to the electrodes by means of short pieces of flexible cable, which connect to the above-mentioned track, and the current is supplied to the track by means of shoes which press against it and form a sliding contact. The electrodes are regulated by means of screws shown, and on small furnaces are entirely hand-operated, but on the larger furnaces automatic electrode control is used, thus doing away with the necessity of close watching on the part of the operator.

In the small furnaces, the door is in one end only, but in the larger furnaces both ends are provided with a door.

Fig. 3 is a photograph of a rear view of a 250-pound Booth electric brass furnace, in the foundry of Leitfelt Brothers, Chicago. This shows the charging door open ready for charging. The latch which holds the door shut when the furnace is charged will be noted and also the electrode projecting through the door. A door of similar type with electrode projecting through it has been in use for a considerable period in the construction of the

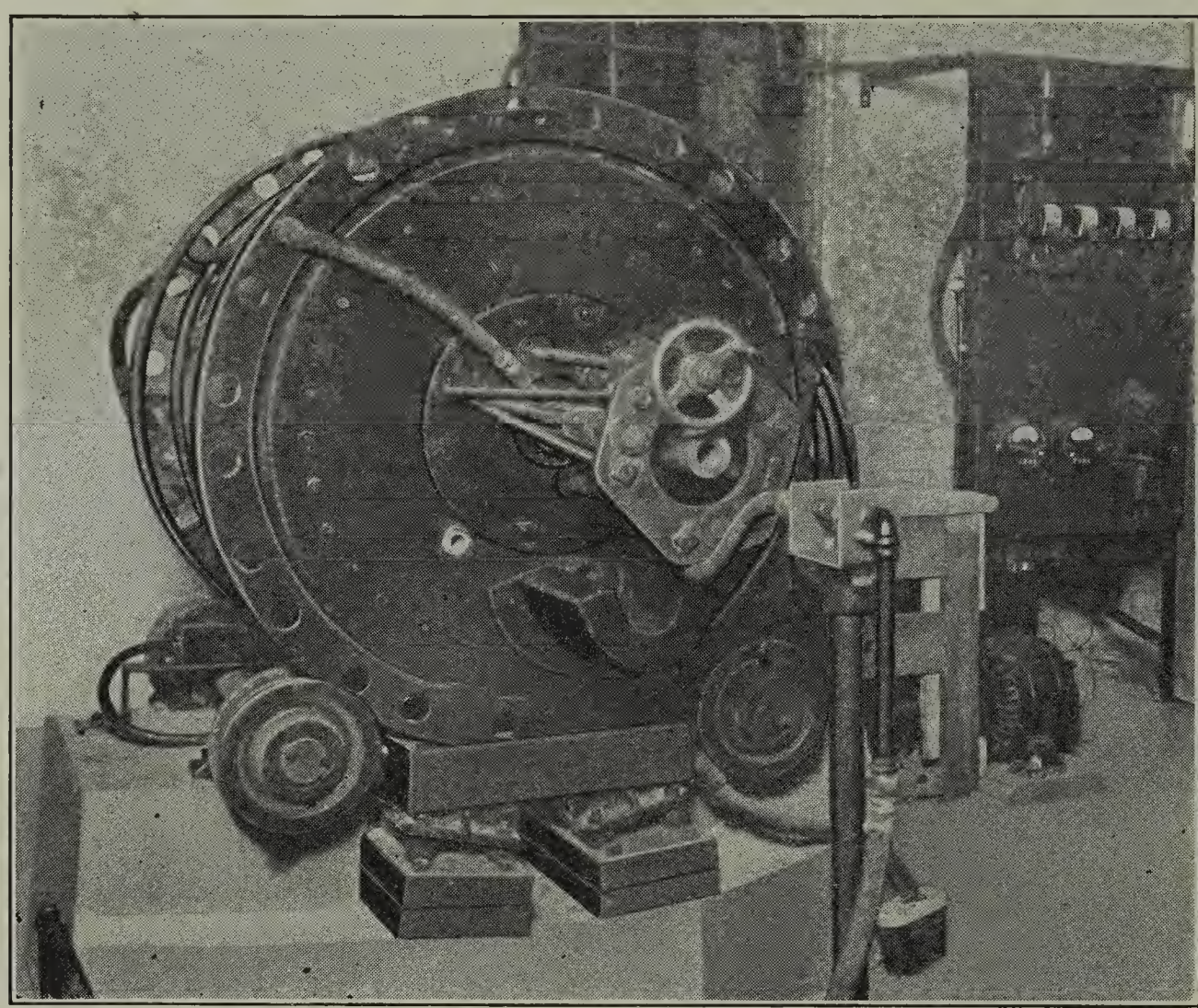

Fig. 5.—Front View of 250-pound Booth Electric Brass Furnace.

Booth-Hall steel melting furnace, built by our company. The contact shoes are shown in this view pressing against the track.

Fig. 4 shows the same end of the furnace as it is charged and the furnace ready to run. The flexible cables from the track to the electrode holder are shown, as are also the water-cooling connections for cooling the electrodes. It is not necessary to open the door until after the heat is poured. The door is then opened for charging.

Fig. 5 shows a front view of the 250-pound Booth electric brass furnace, and illustrates well the cylindrical drum type shell

and the track driven by the rollers. This also shows the bronze shoes which carry the current to the track and the flexible cable connected with the electrode holder and the water connection. The pouring tap is shown directly beneath the electrode holder frame.

Note the switchboard to the right upon which is mounted the controls of the furnace.

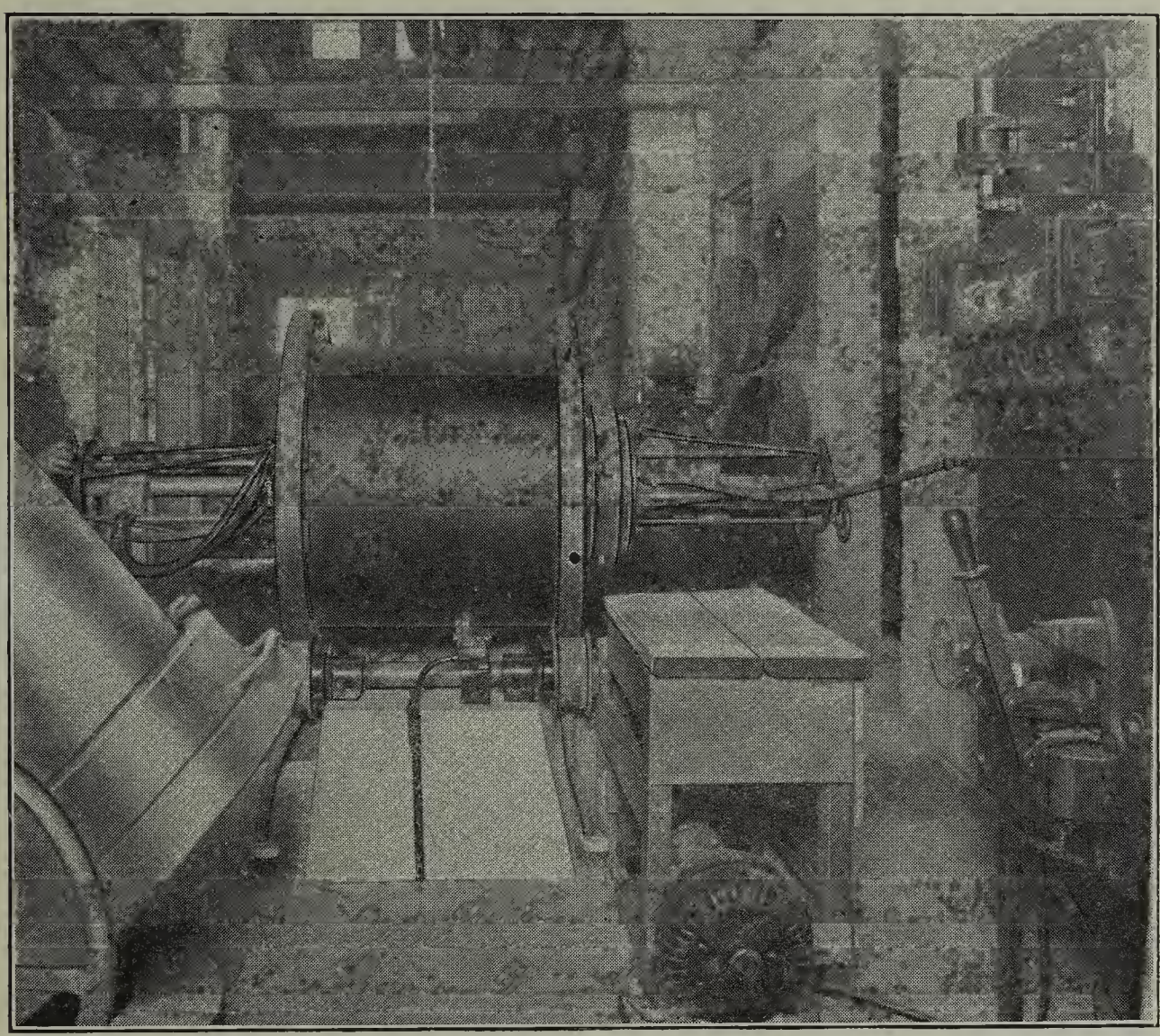

Fig. 6.—Side View of Furnace shown in Fig. 5.

Fig. 6 shows a side view of the furnace. The cable supplying the power to the furnace is shown on both sides, coming from conduits in the floor to the bronze shoes. These are the only connections necessary to carry the electricity to and from the furnace. The operator is shown at the left regulating the flow of the current by means of a handwheel. The contactors are shown on the switchboard, together with push-button control for starting and stopping the furnace.

Fig. 7 shows the furnace pouring. Note the ease with which the men handle the ladle up to the furnace, and the operator con-

trolling the furnace at the switchboard by means of push-button control.

Lining.

Probably the most important of all factors in reliable and efficient furnace operation is the lining. Especially is this true with

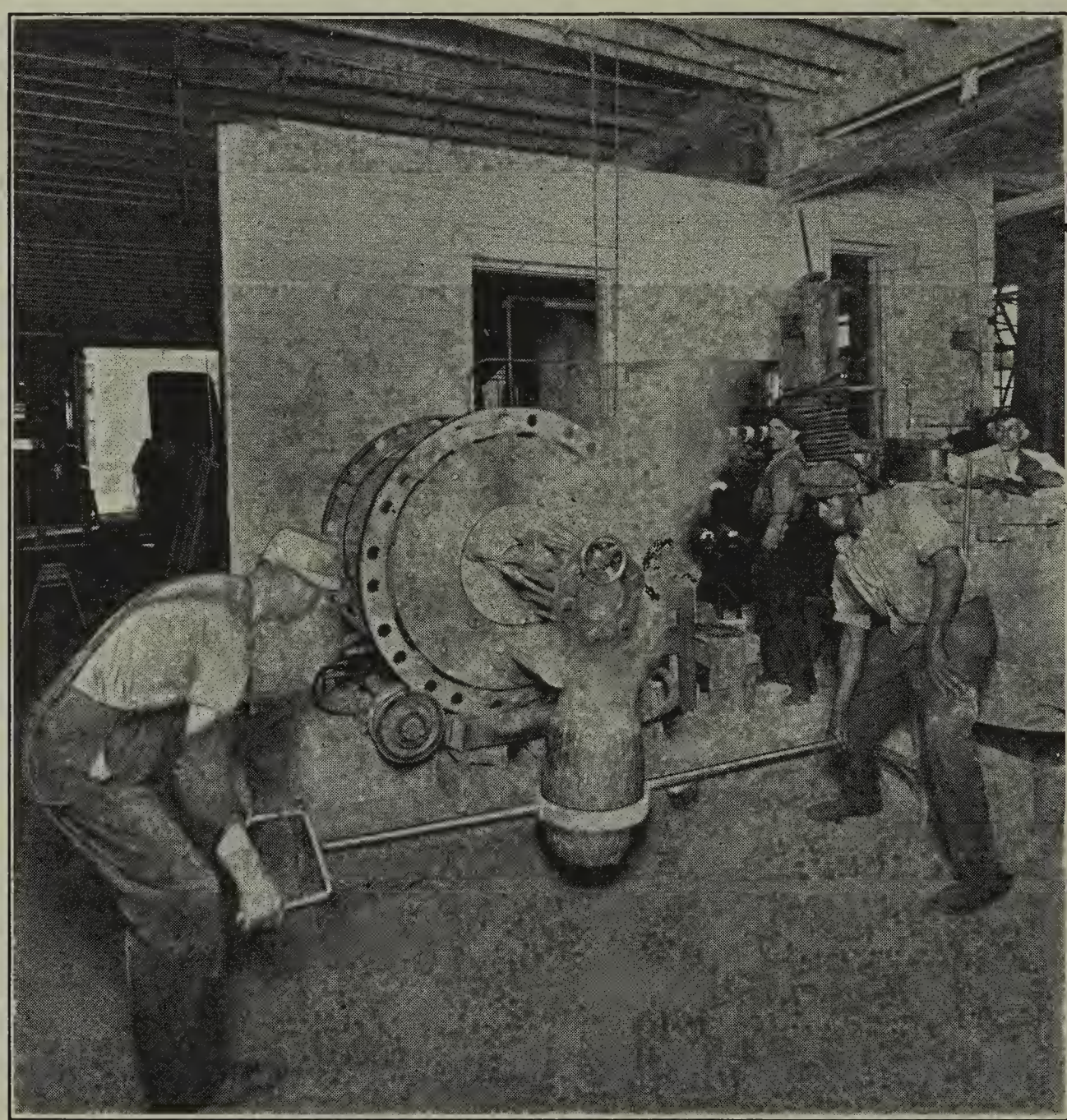

Fig. 7.—Pouring from Furnace shown in Figs. 5 and 6.

the melting of non-ferrous metals, where a lining with many joints will have a decided tendency to absorb metal. In order to overcome this difficulty the lining provided with the Booth furnace is made with as few joints as possible.

In lining the furnace the electrode supporting mechanism at either end of the shell is removed by simply unbolting same from

the end plates. These are made as a unit and in taking them off they do not get out of adjustment or out of line, and therefore do not require any adjusting when put back in place. The shell is then lifted off the rollers by suitable hoist or crane, just as if it were a barrel, and is turned on end so that the end plate of the furnace shown in Fig. 3 can be unbolted and removed from the shell.

Fig. 3 shows to some extent how this lining is made. The door is made of one solid piece of brick with a hole in the center

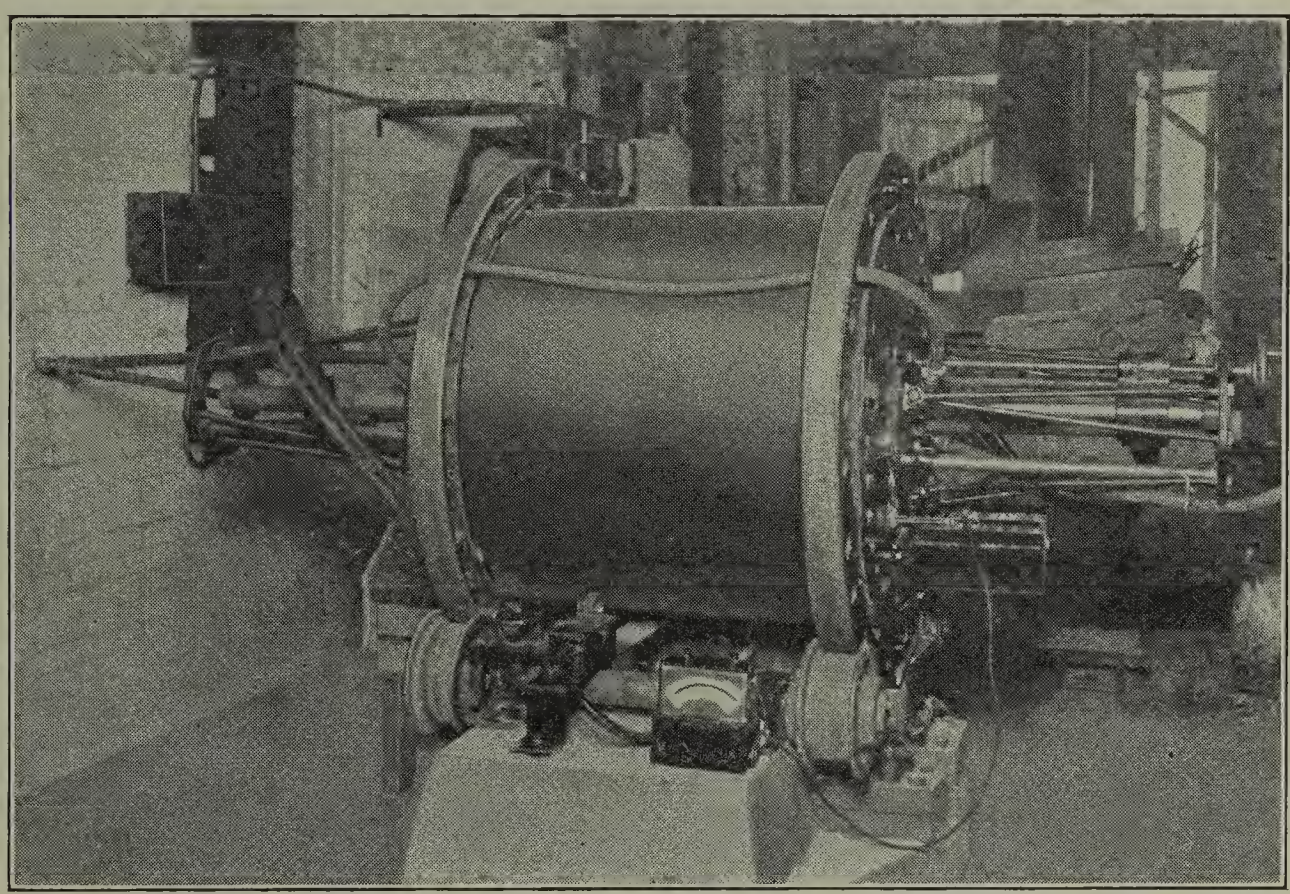

Fig. 8.—Side View of Furnace.

through which the electrode projects. The cylindrical part of the furnace is made of two cylindrical tile, which fit together with a tongue and groove joint in the center, this joint being filled with heat-resisting cement. The ends of the furnace are each lined up with four special brick joined together with cement and cemented to the tile. In this way we really have a large crucible electrically heated, but with walls of considerable thickness, and a minimum number of joints. Further, this lining does not require a brick-mason to install it, but can be put in with common labor. This special brick lining is backed up with a layer of heat-insulating material, so that when the furnace is at working temperature, the temperature on the outside of the shell is so that the hand can

be placed upon it. Compare this with the large amount of heat in the neighborhood of a crucible or other fuel-fired furnace, and it will show you how much easier it is to get men to work around a furnace of this character.

The time required for relining this furnace is 8 to 12 hours.

Furnace Operation. Charging

In starting the furnace the tap hole is plugged with molding sand, the charge placed in the furnace, the door closed and the power thrown on. The electrodes are then brought together by means of the moving mechanism shown in the photograph and the amount of current flowing regulated by moving the electrodes closer together or further apart, as indicated by the meter on the switchboard.

Methods.

If turnings, floor sweepings or grindings are used the rotation of the furnace is started at once and continues until the metal is ready to pour. We have never broken an electrode in operating in this manner. If ingots or heavy scrap is used, the furnace remains stationary until the ingot is partly melted, and then rotation is started and continued until the metal is ready to pour. We have experienced no difficulty in regard to breaking electrodes when this method is followed.

As the furnace is sealed up quite tightly from the time the power is on until ready to pour, we have obtained very good results as to metal temperature by keeping the power practically constant for a definite length of time. After the operator has poured a few heats, it is possible for him to determine the right temperature practically every time without opening the door and inspecting the metal in the furnace.

Pouring.

Fig. 7 shows the furnace pouring and the ease with which the men can bring the ladle to the furnace.

In pouring the furnace, the pipe stands which carry the water connection simply lift out of the way without it being necessary to unbolt anything, and the men can go right up to the furnace with the ladle.

When the furnace is ready to tap the operator stops the rotation until the tap hole is above the level of the holder, and thus above the surface of the metal. The tap hole is then opened by means of a sharp-pointed steel rod. As the tap hole is simply plugged with molding sand there is no sledging or pounding required, as we have found it can be very readily picked out if a small pointed rod is used. We have never had any trouble with the tap hole After the tap hole is opened, the furnace is rotated down until the opening is below the surface of the metal, and the metal poured out into the ladle as illustrated. If it is desired to remove only a portion of the metal, the furnace is again rotated back and the tap hole brought above the level of the metal in the furnace.

On account of the fact that there are no swinging cables connected with the electrode holders, it has been suggested that the furnace itself could be picked up from its rollers by means of a crane and the metal poured into ingots or castings. We have not attempted to do this as yet, but it seems to be entirely feasible.

Operating Records. Metal Charges Used.

With the small furnace which is in the plant of the Leitfelt Bros., Chicago, we have poured about 130 heats, using a great variety of mixtures and pouring a considerable number of different grades of metal. We have used:

Yellow Brass Turnings and Borings.
Concentrates from Floor Sweepings.
Grindings.
Foundry Scrap.
Copper Wire.
Sheet Copper.
Red Brass Ingots.
Yellow Brass Ingots.
Copper Ingots.
Pig Tin.
Lead Pipe.
Pig Zinc.
German Silver.

So that the furnace has been thoroughly tested on many classes of material.

Power Consumption and Shrinkage.

In melting down turnings, borings and grindings with a hot furnace, 30 to 40 minutes is required per charge. With the small furnace shown we have had a power consumption as low as 240 KWH. per ton: the average would be between that and 300 KWH. per ton.

With yellow brass turnings and borings which are fairly clean, but on which no attempt has been made to remove any contaminating material, we have run heats with a total shrink of 1½ per cent. These borings, when charged, were in the same condition as received from the seller. Of course the percentage of shrink will depend on the amount of oil, dirt, iron and other extraneous material present, but the actual metal loss has proven to be very low. Due to the active mixing action of the rotation, the heat is applied to the turnings and borings in such a uniform manner that there is no local overheating, and a quick melt with low metal loss is obtained.

In melting concentrates from floor sweepings, which contain a considerable amount of dirt and moisture, and which when melted in crucibles showed a shrinkage of 30 to 40 per cent, the Booth electric furnace over quite a number of heats averaged 17½ per cent shrinkage.

In melting ingots and heavier brass scrap, a heat will average from thirty minutes to an hour in length of time, depending upon the kind of metal poured and the size of the charges. A 300-pound charge of copper ingots requires about an hour to melt and pour, while a 300-pound charge of yellow brass about forty minutes. The shrinkage with yellow brass ingots averages about 1 per cent, and on red brass and high copper bronze under 1 per cent. With the furnace hot the power consumption will run from 250 to 350 KWH. per ton.

One heat was made with a charge running about 50 per cent zinc and 40 per cent copper, totaling 250 pounds. Two hundred and forty-nine pounds of metal were poured and the power consumption was 240 KWH. per ton. This was in the latter part of the day when the furnace was hot, and the metal charged was all clean metal. The ladle was weighed as it was brought to the furnace, and then weighed after the metal had been poured into the ladle. Great care was taken on the part of the operators not to overheat the

metal, and this is simply an indication of what results are accomplished where sufficient attention is given to melting. The heat following was a charge of 225 pounds of red brass ingots, from which 224½ pounds of metal was poured.

It is particularly difficult to keep account of the metallic shrinkage in a small furnace of 250 pounds holding capacity, and consequently great care has been exercised. Arrangements were therefore made for a scale near the furnace upon which the heated ladle was weighed when brought to the furnace and again weighed when filled with metal. Any drippings from the furnace were carefully collected and weighed and any slag coming out with the metal was skimmed from the pot before weighing, as even a small amount of one pound would mean almost one-half of 1 per cent shrink. With a larger furnace, it would be much easier to make shrinkage tests without danger of as large a proportionate loss, as with the smaller furnace. In other words, if one pound of metal poured did escape being weighed, it would not represent as much shrinkage as in the case of a small furnace.

Lining Wear.

To date about 130 heats have been run and the lining on the furnace illustrated shows no perceptible wear. The lining is sintered upon its surface and appears to be in as good condition as when originally installed. This is the first lining installed in the furnace. The material of which the lining is made is such that it does not shrink, spall or crack, although the furnace is run on an average of eight hours per day. Based on a great many years actual experience in the operation of electric furnaces of many types, our engineers feel confident that linings of this type will last from 600 to 1000 heats, and possibly longer, with proper care on the part of the operator.

Another important characteristic of this method of lining is due to the fact that there are practically no joints, which serves to keep the lining clean and prevents any considerable amount of slag or metal sticking to it.

Electrode Consumption.

With furnaces of this type the graphite electrode is to be preferred, due to its greater conductivity, which permits the use of

the smallest size of electrode practicable for the current to be carried. On this furnace electrodes of 2½ inches diameter are used, machined and equipped with what is known as nipple joint. These are 30 inches in length. The electrodes enter the furnace through graphite sleeves. This opening is also protected by a water-cooled copper casting which serves to protect the electrodes from burning at this point.

Even with the small 250-pound furnace shown, the electrode consumption is low. If the furnace is kept in operation fairly continuously during an 8-hour day, the consumption will average about 3 pounds per ton.

The electrode supporting mechanism has been so designed that it not only permits of adjustment in case electrodes are slightly out of line, but at the same time serves to protect the electrodes from breakage, due to the accidental falling of bars or other material against the end of the furnace.

Power Factor.

A great deal of difference of opinion still exists among operating engineers as to the proper power factor best to be used in connection with electric furnace loads. With small furnaces of the type just described, our judgment is that as low a power factor should be adopted as can safely be permitted with the conditions met with at the point of installation. This can be varied to suit different conditions by modifications in the design of the equipment. If a power factor as low as 70 per cent is permitted, the result will be that the furnace operator need not stay at the electrode hand-wheel control to any great extent, but may be employed in getting his charge ready for the next heat, making suitable records and other miscellaneous duties. If, however, a higher power factor is required, the furnace can be readily operated, but will require more attention on the part of the operator unless automatic electrode regulators are provided.

It is our judgment that in case of installation of a battery of small furnaces, providing a sufficient advantage in power rate could be obtained by obtaining a higher power factor than 70 per cent, it would be best to install automatic electrode regulators. There would also be compensation in reduced labor cost due to the fact

that one man could take care of a large number of furnaces under such conditions.

Labor.

On small furnaces of the size described, one furnace operator can conveniently handle three furnaces without the use of automatic electrode control. This would of course not include the miscellaneous labor for charging and making up the heats, but one extra man could easily take care of this.

Output.

With the 250-pound furnace described by this paper, we can easily charge, melt and pour a ton of metal in 7½ to 8 hours. This same rate of speed is maintained for all sizes of Booth electric brass furnace. With the larger sizes, it will of course take a little longer time to charge and pour, but proper mechanical means can be provided for charging so as to reduce the time to a minimum. If the furnace is used entirely for melting turnings and borings and other small scrap the daily output will be slightly increased.

Advantages. Simplicity.

1. In designing the Booth electric rotating brass furnace it has been our aim to produce a furnace which was efficient enough so that it could be built in small sizes suitable for adoption by the small brass foundry; at the same time such a furnace must be strong and rugged in construction, have few parts and be simple electrically, not requiring the supervision of an electrical engineer or other expert. We believe the furnace described in this paper fulfills all our expectations and will meet the need.

Flexibility.

2. At the same time furnaces of this type can be built in large sizes and offer as many advantages to those plants requiring a large tonnage of brass, as is true with a small foundry.

We have particularly kept in mind the convenience of the operator, the ease with which repairs can be made and of incorporating into the construction of the equipment all details which

will eliminate shut-down either due to mechanical or electrical details.

Economy in Handling.

3. The charging door of the furnace is located at the opposite point from the tapping. If a battery of furnaces is installed in a plant, it is a great deal more convenient and economical both in the labor cost and in the handling of materials to have the charging operations carried on at one end of the furnace, entirely separate from the tapping and pouring. This also saves in floor space as the furnaces can be located very close together under such an arrangement.

Economy in Pouring.

4. In pouring the furnace the tap hole is opened without coming in contact with the metal, and as the furnace is rotated by the motor the metal pours out and can either be collected in ladles or could be poured directly into molds or ingots broughts up to the furnace by approved mechanical means. It is also entirely practicable to pick the furnace up off its rollers and carry it by means of suitable electric traveling crane over to the molds and pour directly into the molds. This method would be especially well adapted for pouring ingot molds or the casting of slabs. After the furnace was poured it would then be returned and set on the rollers, charged and started in operation. Since there are no cables to be disconnected or other electrical connections made, this can be readily done.

Simplicity in Electrical Connections.

5. The absence of overhanging cables and the simplicity of the electrical connections is one of the great advantages of the Booth electric furnace. This is readily apparent and is referred to again simply for emphasis.

Ease of Making Lining Repairs.

6. Where a large number of Booth furnaces are installed in one plant, we recommend the purchase of an extra furnace shell, which

could be kept lined up ready for service. This will be particularly valuable in the case of plant operating on 20-hour basis, as it would save time in shut-downs. The method proposed would be: as soon as the lining of one of the furnaces in use was worn out, the furnace needing a new lining would be lifted off its rollers and the spare furnace set in place, immediately charged and started up without losing more than half an hour's time altogether. The furnace shell which was removed could then be allowed to cool down and new lining placed in it ready for further use.

Low Shrinkage Loss.

7. The important reason why electric furnaces are being adopted by plants melting brass is because of the large saving made in metallic shrinkage. The construction of Booth electric furnace is especially noteworthy in this respect, and all advantages due to the movement of the metal are secured by the rotation of the furnace.

Freedom from Explosions Due to Gas Pressure.

8. Where mixtures are used which might result in the formation of much gas pressure in the furnace, the charging door or doors need not be luted up so as to permit of the escape of the gas pressure without blowing out the end of the furnace, as we understand has been the case in a number of instances where sufficient openings have not been allowed. This can also be accomplished in a very simple manner by leaving the tap hole open for a short time in case it is desired to burn off the oil and dirt prior to the melting of the charge. In other words, with a charge of turnings and borings which are dirty and oily, the furnace can be left in a stationary position with the tap hole open. The furnace being turned around on its rollers so that the tap is located at the top position instead of at the bottom, which would be the position in pouring. This open tap permits the burning oil and fumes to escape. As soon as the operater notes that metallic vapors are coming off, the tap can be plugged up with molding sand and the rotation of the furnace started.

Low Cost of Operation and Upkeep Charges.

9. The complete rotation of the Booth electric furnace results in more even wear of the lining, a greater absorption of heat by

the metal from the same, which naturally results in an improved power consumption. These factors help to bring down the cost of melting and upkeep charges.

Since this type of furnace is new, and we have only had about a month's operation from which to obtain operating data, we cannot get proof from actual records just what the cost of these items will be. The important fact remains, however, that the small furnace described in this paper was successful from the very first heat, has been in daily operation without shut-down from the time the power was first turned on, and the lining does not show any appreciable wear. We are confident that after a suitable length of time has elapsed that the power consumption and other data obtained will show that there is a great advantage to be obtained in rotating the furnace completely.

Uniform Mixing of Charge.

10. The rotation of the furnace not only preserves the lining and secures a low power consumption, but at the same time serves to mix the metallic charge, making it more uniform without requiring much supplementary stirring. Except in the case of mixtures with high lead content, the rotation of the furnace will sufficiently mix the charge so that it is not necessary to stir it either in the furnace or in the ladle. This is quite an advantage and results in a more uniform product.

Standardization to Meet Prevailing Electrical Conditions.

11. In the past the construction of electric furnaces has been along lines which require the use of special electrical appliances and equipment. This Booth electric furnace is a departure. It is entirely practicable to operate it using the ordinary 110-volt single-phase service which can be obtained from most public service companies.

Standardization of Mechanical Details.

12. All details of the furnace equipment are rapidly being standardized so that quick shipment can be made of furnaces, as they are shipped completely assembled and the erection and installation is a simple matter.

In case automatic electrode regulator control is desirable, it should be pointed out that only one regulator would be required, and this could reduce the investment cost materially.

Furnace Can Be Designed to Operate Three-Phase.

13. In the design of large-size furnaces of this type, we have plans perfected for completing the equipment so that it can be operated using either two or three-phase alternating current instead of single phase. This would be important in many cases where public service companies are not in position to handle single-phase loads over 75 KVA.

Summary.

We are convinced that the time is ripe for the adoption of an electric furnace for the melting of non-ferrous metals. For melting of steel and metals requiring a higher temperature, the electric arc type furnace has proved to be the most commercial type of equipment which has yet been developed. This advantage of the arc-type furnace for melting metals at lower temperature has caused inventors to develop furnaces using other methods. These methods require special electrical equipment, however, which must increase investment cost. The Booth electric furnace has been put on the market because as engineers we believe that an arc-type electric furnace was practicable for this purpose and could be built at lower cost than any other type of equipment, and was so simple electrically that the average brass foundryman could operate it without requiring expert handling. The results obtained to date with this first small furnace are convincing and absolutely proves that the principle of design incorporated into our equipment will be successful in securing all these advantages which are sought and claimed for electric brass melting furnaces without the disadvantage of high investment for special equipment and the necessary supervision which it entails.

THE DETROIT ROCKING ELECTRIC FURNACE FOR MELTING BRASS AND BRONZE.

By H. M. St. JOHN

Read at the Boston Meeting, June 18, 1919

In May, 1918, the writer discussed electric brass melting before a gathering of the Ohio Electric Light Assocaition at Cleveland.*

At that time a brief reference was made to a new type of electric furnace which, although of the indirect-arc type, was suitable for use with yellow brass because it was equipped with a rocking device which thoroughly mixed the metal during the melting and superheating operation and thereby prevented the excessive local heating which, in the usual types of arc furnace, results in serious loss of zinc. About a month later the construction and experimental development of this furnace was fully described by Gillett and Rhoads.†

The rocking electric furnace was developed by Mr. H. W. Gillett of the U. S. Bureau of Mines, in co-operation with the Detroit Edison Co., at the plant of the Michigan Smelting and Refining Co., Detroit, Mich. The experimental development was followed immediately by a commercial development, which, during the past year, has resulted in an extensive use of this furnace for melting yellow brass, red brass, and bronzes of various composition. It is the purpose of this paper to discuss the results so far obtained with the rocking furnace in regular industrial use and to outline the possibilities of the furnace in melting brass and bronze.

Before going further it may be well to recapitulate, very briefly, the factors which determine the success of the electric furnace in

* St. John, H. M.: The present status of electric brass melting. Chem. Met. Eng., Vol. 19, p. 321, 1918.

† Gillett, H. W., and Rhoads, A. E.: A rocking electric brass furnace, Jour. Ind. Eng. Chem., Vol. 10, p. 459, 1918; Melting brass in a rocking electric furnace, Bull. 171, U. S. Bur. Mines, 1918.

the brass-melting field. The qualities required in any brass furnace, electric or otherwise, are reliability, speed of production, and the ability to turn out a good quality of metal at a minimum cost for fuel, labor, raw materials, and maintenance. Flexibility, by which is meant the ability to handle practically any alloy under any kind of operating conditions, and the facility with which dirty or finely divided metal can be melted to produce a satisfactory product are important contributing factors. The influence of the furnace on working conditions in the foundry is also a point of considerable importance but one which cannot easily be reduced to a monetary basis for purposes of comparison. In order to make a permanent place for itself in the brass foundry the electric furnace must excel other furnace types in one or more of these particulars and must not fall far short in any.

In the electric furnace reliability depends primarily on simplicity of construction and ease of control. It is permissible to use somewhat complicated control mechanisms outside the furnace, provided that these are largely automatic and are not exposed to high-temperature heat, but within the furnace chamber all electrical and refractory parts must be as simple as possible. If moving parts are used they must be rugged, simple in form and under positive control. Refractory surfaces must be smooth and, so far as possible, unbroken by ledges, corners, and oddly shaped projections. If these requirements are not complied with, the intense heat of the furnace chamber will cause constant trouble with broken refractories, stoppage of moving parts, electrical short circuits, etc., with resultant loss of production and increase of overhead and operating costs.

Ease and simplicity of control are almost equally essential to reliability of operation. Every tool used in the foundry must be capable of enduring a good deal of abuse and rough handling; the furnace is no exception to this rule. A mechanism the satisfactory operation of which demands delicate adjustment and skillful manipulation cannot be expected to perform reliably in this class of service. The control equipment must be as rugged and as simple as the functions required of it will permit, and should not require skilled attendance except at infrequent intervals.

Speed of production depends upon the rate at which heat can be generated within the furnace without injury to the refractories or the metal under treatment, and also upon the efficiency with

which this heat is transferred to the metal. In general, the refractories should not be exposed to a temperature much above the pouring temperature of the metal, if a minimum maintenance cost is to be realized. Since rapid melting requires a considerable temperature difference between the heat source and the metal—except in the case of an induction furnace, where the heat is generated in the metal itself—it is evidently desirable to locate the heat source in the furnace in at least as close proximity to the metal as to the nearest refractories. The efficient transfer of heat from source to metal also demands a high temperature gradient and the shortest possible distance between the two. Above all, there must be no obstacle—such as refractory wall—between the heat source and the metal, as such an obstacle presents a high resistance to the flow of heat and greatly reduces the thermal efficiency.

The production of a good quality of metal depends upon the ease and certainty with which the desired pouring temperature can be attained, the avoidance of undesirable impurities, and a thorough mixing of the alloy in order to ensure uniformity of composition.

The consumption of electric energy per unit weight of metal melted depends upon the rate of power input and upon the thermal efficiency of the furnace. These are the same factors which govern rate of production and which have already been discussed under that head. Of course, the electric energy cost also depends very largely upon the schedule of furnace operation, but this is a factor which affects all furnaces in much the same way and consequently, does not enter largely into a comparison of furnace types. It should be noted, however, that a heavily heat-insulated electric furnace is at a disadvantage if operated intermittently, since such a furnace does not reach its maximum thermal efficiency until it has been operated continuously for several hours, and consequently shows a low average efficiency unless operated almost continuously.

The labor cost involved in melting brass electrically is somewhat indeterminate at the present time, since it varies considerably in different plants and nothing resembling a standardized practice has yet been generally adopted. As a rule, the cost of labor per furnace-day is much the same for all electric furnace types. Since the labor cost per furnace-day is the same for different furnace types, it follows that this element of cost per ton of metal melted decreases directly as the tonnage production per furnace-day increases.

One of the principal items of cost in melting copper alloys, particularly those which contain considerable percentages of zinc and lead, is the loss of volatile metals by volatilization and oxidation. This loss cannot be entirely eliminated, but it can be reduced to a minimum by melting the alloy in a tightly closed furnace chamber, with a neutral or reducing atmosphere, and free from the constant draft inherent in fuel-fired melting, which not only oxidizes the metal but also sweeps away the metal vapors as rapidly as they are formed. As is well known, it is in this point particularly that the electric brass-melting furnace excels, since, in the enclosed furnace chamber, the metallic vapors accumulate and set up a vapor pressure which prevents further vaporization. All portions of the metallic bath must, however, be heated with a fair degree of uniformity. Too intense or too rapid an application of heat to a limited portion of the bath results in raising that portion to an excessive superheat before the colder metal has reached the desired pouring temperature. This condition will result in a rapid loss of volatile metals from the overheated metal when the furnace is finally opened for pouring the heat, since even an electric furnace must be opened for this purpose. If local overheating is very excessive, it may even be impracticable to keep the furnace chamber tightly closed during the melting period and metallic vapors will escape from all available cracks and crevices in the furnace structure, resulting in serious loss.

The maintenance and renewal of refractory linings is an element of cost which depends largely upon the temperature of the heat source, the rate of power input, and the location of the heat source with reference to the refractories. Since a tendency usually exists to push the furnace to the limit of its productive capacity, the furnace of high thermal efficiency, which does not heat any of its refractory parts much, if any, above the maximum metal temperature, will ordinarily show the lowest refractory cost.

The cost of electrodes, carbon resistance parts, etc., depends upon the simplicity of these parts and upon the productive capacity of the furnace. The use of complicated or rapidly consumed resistance parts, or a low rate of melting speed will result in an excessive cost of this nature.

The above discussion covers the more important features of electric brass melting. Now let us see to what degree the rocking electric furnace meets the requirements mentioned, as compared

with other methods of generating electric heat and applying it to the metal in the furnace.

The rocking electric furnace consists essentially of a cylindrical steel shell, lined with suitable refractories, and mounted on rollers and ring gears which permit it to be rocked through any desired arc of revolution up to a maximum of 200°. This rocking motion is actuated by a small induction motor through a reducing gear

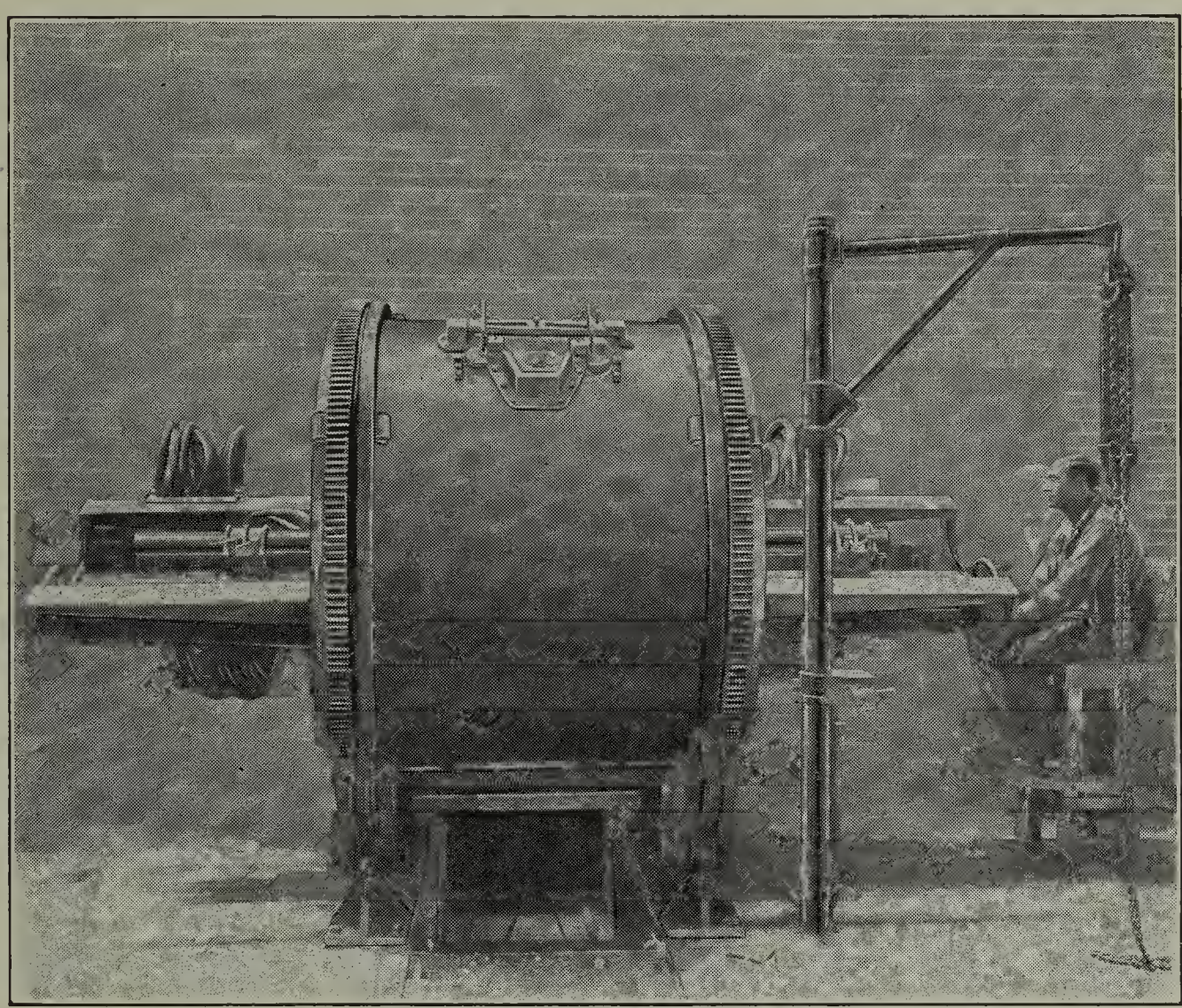

Fig. 1.

immersed in oil and enclosed in a tight gear case. The action of the motor is controlled by an automatic reversing switch which may readily be set to give the desired angle of rock. The source of heat is an electric arc between horizontal graphite electrodes axially placed in the furnace and meeting at the center of the cylindrical melting chamber. These electrodes are controlled by hand wheels which permit them to be entirely withdrawn from the furnace chamber when so desired. One of these electrodes is set

in such a way as to locate the arc approximately at the center of the furnace and is thereafter allowed to remain stationary, while the operator controls the arc by adjustment of the other electrode.

During charging the electrodes are withdrawn until their tips are flush with the inner walls of the furnace in order to avoid striking them with heavy pieces of metal which might cause breakage. The furnace is then closed, the electrodes brought to the

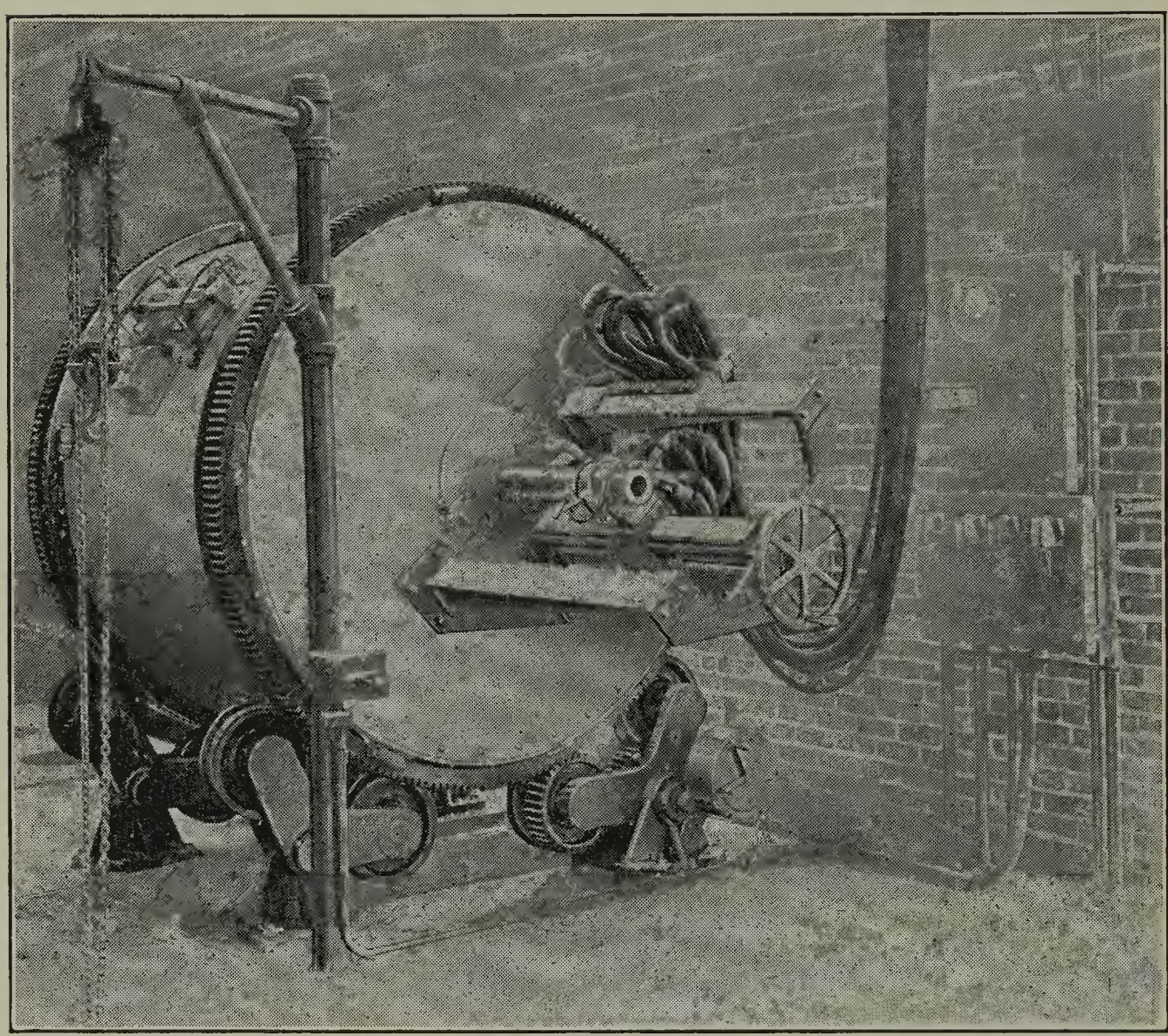

FIG. 2.

operating position, and the arc started. During the first few minutes of the melting period the furnace is not rocked, since rocking at this stage is unnecessary and might cause electrode breakage if started prematurely. As the metal becomes soft, rocking is started, through a small angle at first and reaching a maximum rock as the metal becomes completely molten and enters the superheating stage. During this complete rock the molten metal washes the inner lining of the furnace to within a few inches of the charging door at either

end of the oscillation, at the rate of approximately two complete oscillations per minute.

When the charge is molten, it lies in the lower half of the furnace cylinder at a distance of from seven to ten inches from the arc. The metal is heated by conduction from the entire refractory lining as well as by direct radiation from the arc. The stirring action due to the constant rocking motion of the furnace is sufficiently effective to maintain a constant temperature throughout the melt and thus prevent the surface overheating which would result if the furnace were stationary.

When the melt has reached the desired pouring temperature, the arc is broken and the metal is poured through the spout beneath the charging door. The door itself is not opened until the furnace is ready to charge. If, for any reason, it is impossible to pour the metal immediately, the charge may be held in the furnace without danger of overheating, since no part of the furnace structure is appreciably hotter than the metal. If desired, rocking may be continued during this period, in order to insure a perfectly uniform temperature and a thorough mixture of the alloying metals.

The indirect arc lends itself excellently to the maintenance of a uniform power input and a steady electrical load. After a little experience the operator learns to judge from the kilowatt-hour input how to adjust the rocking of the furnace and when the metal is hot enough to pour. In other words, he knows what condition the metal is in by observing from his meter how many kilowatt hours of heat he has put into the furnace. This is the most convenient and satisfactory method of controlling the temperature, as well as the heat input, and works extremely well, even with an operator of very mediocre intelligence.

The reliability of the furnace is high, since its construction is both simple and rugged. Its cylindrical form permits the strongest possible refractory structure; the method of heat generation is simple and involves no complicated parts, electrical or otherwise; the gears and other parts of the rocking mechanism are sturdy and not exposed to high temperatures, while the electrical control mechanism is as simple as it can be made and very seldom a source of trouble. There is nothing complicated about the controls and even the greenest of operators rapidly becomes proficient in their use.

The power input of the furnace is relatively large and its

thermal efficiency high, this desirable combination resulting in a high productive capacity. The arc is not more than ten inches from the metal on a full charge, while it is approximately eighteen inches distant from the nearest refractories—the vertical end walls—and twenty inches from the cylindrical walls. This makes possible a rapid rate of heating without injury to the refractories, while overheating of the surface layer of the metal nearest to the arc is prevented by the constant mixing which it undergoes. Using 2000-pound charges, the rocking furnace will produce approximately 2000 pounds of molten brass per hour, melting time, or about 1500 pounds per hour, elapsed time, the latter including time consumed in charging, pouring, and incidental delays. This is a higher productive capacity than can be obtained with any other electrical brass-melting furnace of similar size.

As already stated the quality of the metal produced is a function of temperature control, thorough mixing, and the absence of impurities. Any electric furnace which does not burn the metal makes possible the avoidance of impurities and thus compares favorably with fuel-fired furnaces, which expose the metal to a rapidly moving, oxidizing atmosphere which also contains sulphur and other undesirable products of combustion.

Accurate temperature control is difficult in those types of electric furnaces which heat their refractory walls and roofs far above the metal temperature, thus causing the metal to absorb heat even after the electric current has been turned off. In an arc furnace the heat input stops immediately when the switch is opened and metal can be held in the furnace indefinitely without danger of overheating.

In the rocking furnace a perfect mixture of the metals which go to make up the alloy can readily be attained, by virtue of the brisk agitation which the molted metal receives. Even high-lead alloys can be poured from the furnace in perfectly homogeneous mixtures. The table below shows the results obtained with a series of heats, from which samples were taken of the first ingot from the first ladle and the last ingot from the last ladle in each case. The variation in a composition from heat to heat was due to the selective absorption of lead by a green furnace lining. While the variation in lead content between the first and last ingots of any heat is very small it will be noted that, in three cases out of four, the percentage of lead in the first ingot is higher than that in the last.

TABLE I

Heat No.	Ladle No.	Per Cent, Cu	Per Cent, Sn	Per Cent, Sb	Per Cent, Pb	Per Cent, Zn plus Impurities.
1	First.....	72.73	4.97	0.61	21.02	0.67
1	Last.....	72.12	4.88	0.61	20.97	1.42
2	First.....	68.89	4.86	0.61	23.19	2.45
2	Last.....	69.09	4.47	0.61	22.96	2.87
3	First.....	66.51	4.24	0.61	25.49	3.15
3	Last.....	67.15	4.30	0.61	25.28	2.66
4	First.....	67.07	4.30	0.61	25.02	3.00
4	Last.....	66.01	4.47	0.61	25.87	3.04

It is, of course, frequently very important to duplicate a complex alloy, for heat after heat, with a minimum deviation from the specified composition. Table II shows how exactly this can be done with the rocking furnace. The figures given in the table

TABLE II

Heat No.	Per Cent, Cu	Per Cent, Sn	Per Cent, Pb	Per Cent, Zn	Per Cent, P
45	86.90	8.35	1.63	3.04	0.015
46	87.18	8.43	1.09	3.28	.020
47	86.68	8.37	1.37	3.56	.020
48	87.24	8.36	1.26	3.10	.020
49	86.84	8.20	1.21	3.73	.014
50	86.94	8.10	1.04	3.91	.014
52	87.80	7.64	1.36	3.20	.020
53	87.16	8.27	1.30	3.26	.014
54	86.96	8.27	1.33	3.43	.010
55	96.82	7.98	1.21	3.96	.025
56	87.20	8.27	1.25	3.27	.014
57	87.12	8.27	1.23	3.36	.016
58	86.80	8.59	1.21	3.39	.013
Average.....	87.05	8.24	1.27	3.42	.017
Max. deviation from average.....	0.75	0.60	0.36	0.54	.008
Average deviation from average....	0.22	0.26	0.10	0.23	.004

are taken, not from a special test, but from the routine analysis for thirteen consecutive heats from a rocking furnace melting phosphor bronze.

The thermal efficiency of the rocking furnace is high, and the energy consumption per ton of metal melted is correspondingly low. The thermal efficiency of the furnace is considerably higher than that of any stationary type of indirect-arc furnace, even higher than that of the direct-arc furnace. It is more nearly comparable to the efficiency of the induction furnace which, since the source of its heat is in the resistance of the metal itself, does not heat its refractories to a temperature higher than that of the metal and consequently enjoys the advantage of minimum radiation losses, as well as an utter absence of electrode heat losses. The high efficiency of the rocking furnace is primarily due to the fact that approximately four-fifths of the inner refractory lining is washed by molten metal, due to the rocking action of the furnace. Most of that part of the lining which is exposed to direct radiation of heat from the arc, and thereby becomes hotter than the metal, is intermittently brought into contact with the latter and gives up its excess heat to the metal instead of expending it uselessly through the outer walls. The furnace refractories are thus subjected to a constant cooling action and are maintained at a relatively low temperature, with the result that radiation losses are a minimum, appreciably lower than would be the case if the furnace were operated in a stationary position.

The comparatively low refractory temperature in the rocking furnace makes it possible to obtain a high thermal efficiency without an excessive thickness of heat-insulating wall. As a result, the temperature lag of the furnace is moderate and, when operating from eight to ten hours per day ,the furnace reaches its maximum efficiency on the third heat of the day, an important consideration in intermittent electric furnace operation.

The number of kilowatt hours required per ton of metal varies widely, depending upon operating conditions and upon the nature of the alloy melted. One large rolling mill, operating the furnace sixteen hours per day on 60-40 brass, gets a minimum consumption of less than 200 kilowatt hours per ton and has averaged 224 kilowatt hours over a total of several hundred heats. Average eight to ten-hour operation on clean scrap and new metal mixtures shows about 250 kilowatt hours for yellow alloys, and 275 kilowatt hours

for red alloys. If a high proportion—over 50 per cent—of very oily or wet borings and grindings are included in the charge, the energy consumption on 2000-pound charges may run as high as 300 kilowatt hours per ton.

The ability to handle very dirty borings and fine scrap of all kinds, whether red or yellow, is an advantage peculiar to the rocking furnace. It is possible in this furnace to melt satisfactorily a charge consisting wholly of dirty yellow borings and grindings, without opening the furnace after melting begins, something which can hardly be done in any other furnace without mechanical rabbling accompanied by high metal loss.

Although, as already mentioned, the labor cost per furnace-day with furnaces of similar size does not vary greatly from one electric furnace to another, the high productive capacity of the rocking furnace makes possible a very low labor cost per ton of metal melted.

The importance of the metal saving effected by any properly designed and correctly operated electric furnace is well recognized. In the rocking furnace clean yellow brass can be melted with a net loss below 1 per cent. With red mixtures the net loss is, of course, less than with yellow metal, usually not above 0.5 per cent. Borings and fine, dirty scrap can be melted with far less loss than is the case in any type of fuel-fired furnace, or in any type of electric furnace where mechanical rabbling is necessary, although the loss is, of course, higher than with clean scrap or new metal mixtures. Metal losses under 2 per cent when melting very dirty borings and cuttings are by no means unusual, this with metal which must ordinarily be melted in a reverberatory furnace, with complete loss of the volatile constituents of the alloy. Red borings, if not too dirty, can be melted with a loss practically as low as that experienced with clean red scrap or new metal.

The rocking furnace has introduced one decided innovation in brass foundry practice. With this furnace it is not only possible, but even highly desirable, to add spelter with the rest of the charge at the beginning of the heat, when melting new metal or making up a deficiency of zinc in a scrap charge. This not only saves the time ordinarily consumed by the speltering operation but also avoids the necessity of opening the furnace for this purpose, with the attendant loss of metal and heat. Tin and lead should also

be added with the rest of the charge rather than at the end of the heat.

The excellent showing made by the rocking furnace, as compared with other types of arc furnaces, with respect to metal loss, is due to the rocking motion of the furnace, with the resultant agitation of the metal, which eliminates all danger of local overheating of the charge.

The rocking feature of the furnace also plays an important part in prolonging the useful life of the refractory furnace lining. The continual washing to which most of the lining is subjected cools the refractories to a temperature only slightly above that of the metal itself, well below the critical temperature of the refractory brick used. The brick selected for this service is of such a nature that erosion by the constantly moving metal is not a serious factor. A single lining of corundite brick lasts for about 350 heats in average practice, at which time it requires more or less extensive patching. Under normal conditions it is never necessary to entirely replace this inner lining, while the intermediate and outer linings ordinarily require no attention. One user of the furnace reports having obtained 600 heats from his first lining, on intermittent operation, and states that he expects to obtain from 900 to 1100 heats on continuous operation. Under average conditions the refractory cost is less than $0.50 per ton of metal melted.

The electrode consumption is from two to three pounds per ton of metal melted, or, at present prices, from $0.50 to $0.75 per ton of metal. This compares very favorably with the best arc furnace practice in such installations as use the stationary type of arc furnace for melting copper alloys.

The overhead cost of melting with the rocking furnace is low, particularly in such installations as take full advantage of its inherently high productive capacity. The first cost of any electric furnace is rather high and the canny user will see to it that the furnace is busy melting metal for as many hours in each day as his manufacturing schedule will permit.

One more point which is of particular interest for the central station company and others who supply power for electric furnace use. The electrical characteristics of the rocking furnace are such as to cause the furnace to be considered a highly desirable power load. As compared with arc furnaces in use for steel melting, its demand is exceptionally steady and free from violent fluctuations,

while its average power factor is from 85 to 95 per cent. Its maximum demand is less than 300 KW., and the load which it imposes on the power line is so steady as to result in little or no inconvenience to the average central station company or to those of its customers who may take power from the same line.

In summing up the experiences of those manufacturing concerns who are using the rocking electric furnace in their daily practice, it can safely be concluded that this type of furnace has created new possibilities for electric melting in both rolling-mill and brass foundry work. It combines the high productive rate of the electric arc furnace with the low metal losses and high quality of metal which have been the goal of electric furnace development in this field. In reliability of operation and ease of control it is second to no other type of electric furnace. In its use of electric energy it shows an efficiency approximately on a par with the induction furnace, which means, practically speaking, the highest efficiency which can be obtained from any electric furnace design. Its overall economy of melting operation is at least as favorable as that of the induction furnace and better than that of any other type. In flexibility of use it stands alone, since it is daily proving its ability to melt satisfactorily, under conditions of either continuous or intermittent operation, all of the commonly used copper alloys, as well as several less common metals and alloys not ordinarily considered in a discussion of brass melting. This includes dirty borings and other fine scrap with a high non-metallic content, which are usually consigned to the reverberatory furnace for lack of a better method of handling them.

It is desired to emphasize the fact that it is the rocking feature of the furnace which makes possible the use of an arc in melting alloys containing a high proportion of volatile metals, a consummation which the writer of this paper, for one, long believed to be practically impossible. The use of this principle also results in a homogeneity of the alloy as poured from the furnace, which is very difficult of attainment in any other type of furnace, particularly with reference to the high lead alloys.

There is one other consideration, particularly apropos at this time, which applies to the use of any properly designed and operated electric furnace in any brass rolling mill or foundry. In the past great emphasis has been laid upon the ability of the electric furnace to produce a high grade of metal economically, and particu-

larly with a marked saving of zinc and other more or less volatile and easily oxidizable metals. These factors are of importance and deserve the attention which they have received. But one feature which has received far less attention, largely because its value could not readily be spelled out in dollars and cents, is rapidly becoming of paramount importance. The electric furnace makes the brass foundry—even a rather poorly designed and old-fashioned brass foundry—a decent place in which to live, breathe and have one's being. In these days of labor unrest no manufacturer can afford to overlook this point, even if he feels quite sure that his present fuel-fired practice leaves nothing to be desired so far as economy of operation is concerned.

DISCUSSION.

President Little: Gentlemen, I am sure you will all agree that we have had a peculiarly instructive and informing morning. We are not only greatly indebted to the several speakers, but I want to bring to your attention the fact that we are particularly indebted to Mr. Bragg by whom the symposium was arranged, and who has been largely responsible for securing the various papers.

Dr. A. C. Langmuir: Has anything been done in the use of electric furnaces for melting cast iron in foundry practice?

Mr. H. M. St. John: There has been some experimental work along that line but we have not done any of it in the Rocking Arc Furnace. The method has certain advantages, but there is still some question as to its overall economy. The chief advantage is the elimination of sulphur which, in cupola melting, accumulates and eventually causes trouble. In one plant cast iron is now being melted in the cupola and then transferred to the electric furnace where it is refined.

Dr. Langmuir: I was prompted to ask that by the fact that we are now paying 8½ cents a pound for iron castings.

Mr. Booth: I might direct the gentleman's attention to the Luckenheim Company's experience in that matter. They have had a great deal of experience in taking castings and I am sure they would be glad to give you the benefit of their experience, and that an inquiry addressed to them or to their chief metallurgist will undoubtedly get a full reply.

Mr. Howard: I would like to ask if this furnace has been made for melting cement copper precipitated in metallic form.

Mr. St. John: No, it has never been used for that purpose, but I see no reason why it should not be applicable. No definite statement can be made at present since this particular application of the furnace has not yet been tried out.

Mr. H. K. Moore: I would like to ask if in making his refractory linings he has done any work on shrinking brick before it is put in the furnace? We find in what work we have done on electric furnaces that the preliminary shrinking of the brick adds greatly to the length of the life of the brick, due to the greater compactness of the brick resulting from the elimination of the greater part of its pores.

The President: Will Mr. Moore indicate how that shrinkage is carried out?

Mr. Moore: We do the shrinking that we do on pure magnesium oxide brick and we treat it electrically until we almost fuse the magnesium oxide, and although it is not absolutely non-porous brick it comes very close to being non-porous brick.

Mr. Gillette: I wish you would give us some more details of that.

Mr. Moore: I am in the paper business and not in the brick or metal business, but we do have a proposition of smelting sodium sulphide, and it does require as you know an alkaline brick. The trouble with the usual brick in smelting sodium sulphide is that the variation in the content of oxygen in the furnace is liable to change the sodium sulphide into sodium sulphate, and you have an expansion in the brick and a constant sloughing action going on, and we have to fill up those pores absolutely to prevent this sloughing action. The only way we have found to do that is to take the magnesium bricks and put them into an electric furnace at enormous temperature, and sometimes we press them after the softening has taken place. In some cases we add a very minute amount of flux which will soften them to the required point. That has to be added with a great deal of care, but the practical result is that the brick which is shrunk will last between six and seven times the length of a brick which has not been shrunk.

RESULTS OBTAINED WITH HIGH FREQUENCY INDUCTION.

By E. F. NORTHRUP

Read at the Boston Meeting, June 18, 1919

The Ajax Metal Co. of Philadelphia, Pa., has been backing the writer for nearly three years in the development of high frequency induction methods of electric heating.

Numerous experimental furnaces of various forms and sizes have been constructed and tested, the early forms in the Palmer Physical Laboratory of Princeton University, and later ones at the plant of the Pyrolectric Instrument Co. of Trenton, N. J.

The development is too new to enable references to be made to many furnace installations which are operating in customer's hands. Several installations, however, which aggregate about 120 K.V.A. have been sold and are now serving useful purposes in the hands of the users. Among these users might be mentioned the Corning Glass Co., the Baker Platinum Co., The Westinghouse Electric Co., The Nela Laboratory and the Bureau of Standards. Plans have been formulated and quotations made for the handling of commercial melting and heat treatment of materials calling for an aggregate of several hundred kilowatts.

The principles of heating by high frequency induction and technical descriptions of how these principles have been applied have been so fully presented elsewhere* that these remarks shall be con-

*NORTHRUP-AJAX FURNACE BIBLIOGRAPHY TO FEB., 1920

Transactions of the Faraday Society, Vol. XIII, 1918. "Production of High Temperature and its Measurement," by E. F. Northrup.

Chemical and Metallurgical Engineering, August 1, 1918. Pages 155, 156. "Northrup-Ajax High Frequency Induction Furnace."

Transactions of American Electrochemical Society, covering April 3-5, 1919 meeting, held in New York, "Principles of Inductive Heating with

fined chiefly to statements of the present status of the development and to what has and can be accomplished by this most effective method of electric heating.

In heating with high frequency currents it is presupposed that high frequency power is available in sufficient amount to give the results desired.

For power units of moderate size the necessary high frequency current may be obtained with great simplicity from commercial A.C. single phase or polyphase circuits. The voltage of these circuits must be adjusted by means of transformers to about 6600 volts. With this voltage available 20 or 25 kilowatts per phase can be utilized. The high voltage is used to charge static condensers which in discharging through an inductor heating-coil, and with the natural oscillation period of the circuit, yield the required high frequency current. By multiplying the units any amount of power can be utilized in this way. However, for large power installations, where a single furnace calls for over 100 kilowatts, other sources of high frequency power will probably be used to advantage. An ideal source of such power is the high frequency alternator of the Alexanderson type. These machines have been in service in wireless work and have proved their reliability in single units of 200 K.W. output. The General Electric Co. which manufactures them is said to have ten under construction at the present time.

High Frequency Currents," by E. F. Northrup. Eighty-eight page article on the mathematical and physical theory soon to appear in the yearly transactions.

Pyrolectric Monthly Bulletin No. 3, April, 1919. "Production of Carbon Free Alloys of High Melting Point," by E. F. Northrup. *Out of print.*

Electrical Record, April, 1919, pages 245-247. "High Frequency Induction Furnace."

Chemical and Metallurgical Engineering, April 15, 1919. Pages 371-382. "Principles of Inductive Heating with High Frequency Currents."

The Iron Age, May 15, 1919. Pages 1294-1295. "High Frequency Unit for Making Carbon-Free Alloy of High Melting Point."

Chemical and Metallurgical Engineering, Sept. 1, 1919. Pages 258-259. "Electrical Production of Carbon Free Alloys."

Electrical Experimenter, September, 1919. Page 410. "Possibilities of High Frequency Currents," by John F. Pritchard.

Circular, Henry Coe and Clerici, Milano, Italy. "Fornace Elettrica ad Induzione." (In Italian.)

Pyrolectric Monthly Bulletin No. 7, September, 1919. Page 2. "Northrup-Ajax High Frequency Induction Furnace."

No high power high frequency alternator has thus far been at the disposal of the writer for either experimental or commercial purposes, but he is expecting soon to make tests with one of the existing machines.*

Results obtained with the oscillatory discharge of condensers, and on one occasion with a small power high frequency alternator as a source of high frequency current, have recently been uniformly good and are extremely convincing of the usefulness and vast possibilities potential in this method of heating.

In electric heating two chief ends are sought:

(*a*) The attainment of reliable electric heating at a moderate temperature of a relative cheap material, as German silver, brass, etc., with sufficiently good power efficiency to make the method successful in competition with other existing commercialized electric heating methods, and

(*b*) The heat treatment of valuable products, as high speed steel, magnet steel, gears, springs, etc., and the attainment (preferably, under carbon free conditions) of excessively high temperatures for producing fusion of high melting point and valuable products, as platinum, osmiridium, refractory oxides, etc. Here high power-efficiency is a secondary consideration. The sintering of tungsten and molybdenum bars, requiring respectively about 2800° and 2300° C., would come under this head.

Though the development of high frequency inductive heating has reached a stage where designs of specific apparatus can be made which are based upon thoroughly established formulæ no large power apparatus has yet been constructed. An outfit yielding 40 kilowatts, but not at all modern in design has been available for experimental and efficiency tests; but in the light of later developments and of improved designs these efficiency tests do not do adequate justice to the method. Nevertheless the showing in power-efficiency of these tests is far from unsatisfactory. A two-phase equipment, manifestly deficient in many respects, has been operated

* Since writing this article the writer has had the opportunity, through the courtesy of the General Electric Company, of making use of a 200 kilowatt Alexanderson machine. Temperatures were obtained which were nearly but not quite adequate for the sintering of tungsten. Efficiency tests were made of the melting of copper and when registering the power input at the furnace terminals the overall efficiency obtained was 77 per cent, which with better designing of the furnace would certainly have reached 80 to 82 or 83 per cent.

at 30 kilowatts in making an efficiency test on the melting of yellow brass. The power input was measured at the switch terminals and hence included all possible losses in reactances, transformers, condensers, discharge-gap, leads, radiation losses from furnace walls, etc. The test was made with the furnace having a crucible holding about 180 pounds of brass. The furnace melted 4.8 pounds of brass per kilowatt hour. As 12 pounds per kilowatt hour is the theoretically 100 per cent efficiency figure, this means a melting efficiency for this particular furnace of 40 per cent. There is, however, little doubt in the writer's mind that with the improved apparatus of the oscillatory current type available, which has been planned, the melting efficiency for brass will attain 50 per cent or better. When high frequency power from alternators becomes available the melting efficiency should reach figures approximating 75 to 85 per cent or brass should be melted at the rate of nine to ten pounds per kilowatt hour.

For the melting of such valuable products as special high-grade steel, high-grade ferrous alloys and the precious metals, gold, silver, and their alloys, the melting efficiency is thought to be quite adequate if it equals or exceeds 40 per cent.

The great value of the furnace for a melting furnace, however, appears from a consideration of the following features which it possesses in a unique degree.

1. All the heat supplied is generated directly within the melt itself or the walls of the crucible which contain it and the melting efficiency does not fall off, as is the case with resistor-type furnaces, with an increase of the melting temperature of the product being treated.

2. Melts may be made in slightly conical crucibles and allowed to freeze and the solid mass may be again melted without cracking the crucible, or it may be dropped out of the crucible, by inverting this, as a solid mass.

3. Materials in masses weighing 100 to 200 pounds can easily be raised to temperatures which exceed 1600° C. The furnace is thus adapted to the making and melting of pure iron, nickel, cobalt, chrome, and other like alloys.

4. The mass of refractory required for heat insulating the melt weighs but a few pounds and under certain conditions less than a pound. Thus starting the furnace cold the melting temperature is attained by the crucible wall in a few minutes, always in less than

Edward Bartow

half an hour. Melting operations are therefore started with extreme rapidity. For example a batch of Pyrex glass contained in a crucible 10 inches deep and 5 inches inside diameter, may be raised from room temperature to its required fusion temperature, between 1500° and 1600° C., in less than half an hour.

5. The furnace works at highest efficiency when its inductor coil is made of a flattened copper tube through which is kept circulating about two pounds of water per minute. The outside wall of the furnace is, therefore, always under 100° C., and working around it and with it is a great comfort.

6. The temperature throughout the mass being heated is almost absolutely uniform and can be held under perfect control. Reduction of power to the furnace to lower the temperature does not involve waste of power.

7. Since energy flows into the mass to be heated solely by induction the adaptation of the furnace to vacuum-heating or heating in special atmosphere is extremely simple.

It is, however, when we come to the use of the principle of high frequency induction for the attainment of excessively high carbon-free temperatures and the heat treatment of intrinsically valuable products that we enter a field in which the furnace has absolutely no competitor. If the material is a conductor it need only be imbedded in a highly refractory sand and heated by the currents induced within itself to any desired temperature. In a series of experiments conducted with the object of attaining high temperature many refractory oxides, including cobalt and chromium oxides have been successfully fused.

The making of all species of carbon-free alloys, where the lower melting constituent fuses under 2000° C., is readily accomplished using the present commercialized sizes of oscillatory current furnaces now available. Many carbon-free alloys of pure electrolytic iron with copper, nickel and molybdenum have been made by the writer and their micrographs taken.

A fully worked out mathematical theory of this system of heating, verified by practical experiments, proves that it has fewer limitations in respect to efficiency of heating and for the attainment of the highest carbon-free temperatures than any other electric method thus far adopted or proposed.

Sufficient time has not elapsed, however, so that it has been possible to put into practical commercial form apparatus which is

suitable for adopting the principle to the very many industrial requirements to which it is ideally adapted.

Small size units, adapted to absorb 20 K.W. per phase from a

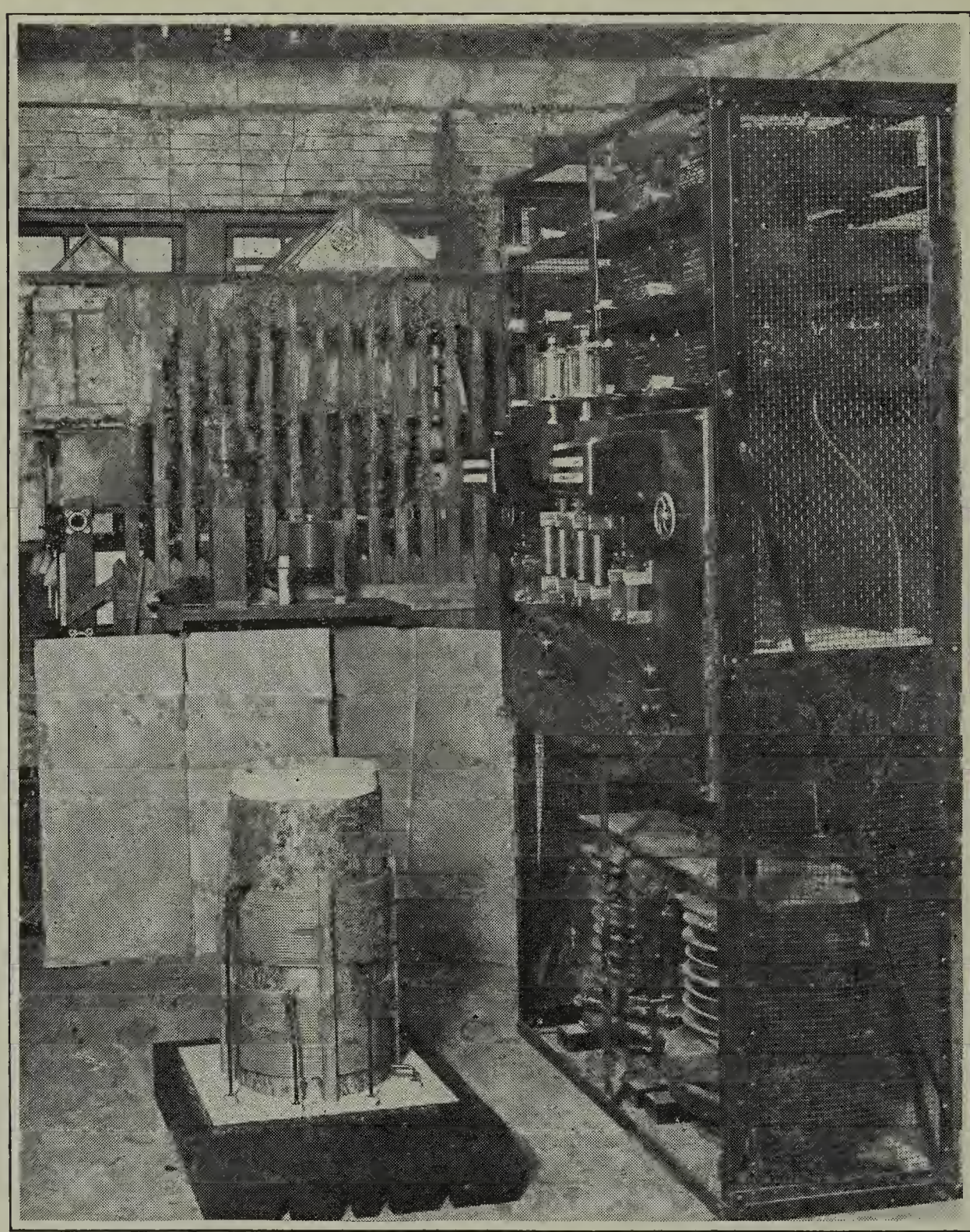

Fig. 1.

polyphase circuit, are now being manufactured by the Pyrolectric Instrument Co., in forms which are simple and entirely practical for placing in the hands of customers and the several such which are now in service appear to be giving satisfaction to the users.

Illustrations are here introduced of a typical two-phase oscil-

latory current high frequency generator and two types of furnaces. The high frequency generator shown on the right in Fig. 1 draws 16 kilowatts from each phase of an ordinary 60-cycle, 220 volts, supply line. It is thus adapted to operating a 32-kilowatt furnace. A furnace of the dipping type, intended for melting silver, is shown also in Fig. 1. The enclosing casing around this furnace is removed to better reveal the construction of the furnace. The two inductor coils shown are connected one to one-phase and one to

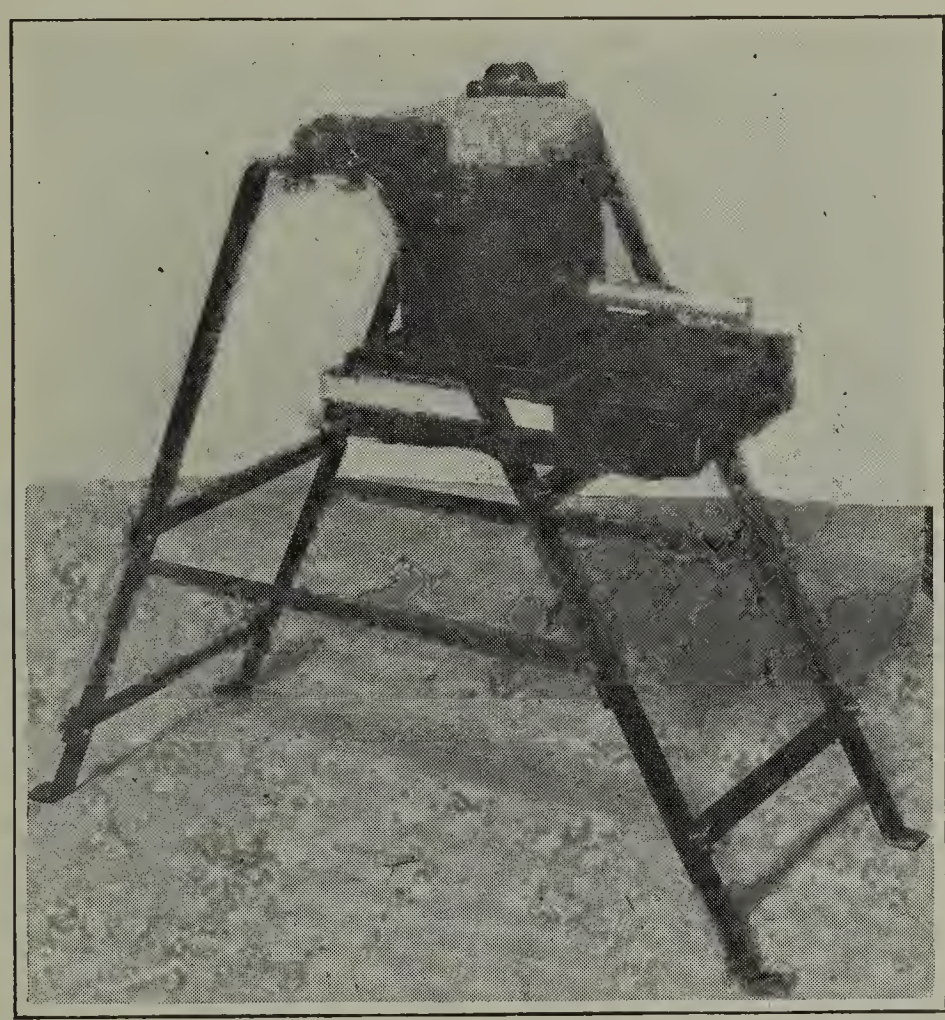

FIG. 2.

the other of a two-phase generator system. These coils consist of flattened copper tubing through which circulates a small stream of water. The outside of the furnace is always at a temperature of less than 50° C. even though the temperature of the charge is raised as high as 1400° C., which is about the upper limit of this particular design of furnace. The crucible has an inside diameter of 10 inches and is 20 inches tall.

In Fig. 2 is shown a type of small tilting furnace especially designed for the rapid melting of gold. The furnace is charged

from the top and the three or four pounds of gold, which the furnace holds, is melted in from four to five minutes when operated by a 12 K.W. high frequency generator set.

The leads coming from the high frequency generator set may be connected to furnaces of many different styles and types. The costly part of the installation is the high frequency generator set, but this has a very small depreciation. The furnaces proper are of very simple construction, as the illustrations here reproduced indicate.

It is expected that an intensive commercialization of the system of high frequency inductive heating will continue and that reports on commercial installations will not be long delayed.

PALMER PHYSICAL LABORATORY,
Princeton, N. J. Princeton University.

DUSCUSSION.

C. A. WINTER: Just one point that I want to bring out this afternoon, which was touched on this morning by Mr. Gillette, and I believe deserves a little more consideration that has been given it, or perhaps than he has given it, and that is the effect of the economics of fuel in the cost of your finished material, brass. He spoke of the fluctuating price of fuel, oils and so forth, in the melting of brass, and spoke of the stability in the cost of electric power. You can carry that a step further and point out the trend of the cost of other fuels for any purpose, particularly in the melting of non-ferrous alloys and show that the cost of oils and other fuels have actually gone up until in the last few years they have increased 100 per cent and will continue to increase for the specific reason that their main cost is common labor, an element which is being reduced to the irreducible minimum. On the other hand electric power has not increased nor will it increase at the same rate, for one very fundamental reason. And that reason is that at the present time the thermal efficiency of the generating station is about 20 per cent. We are in the infancy of the generation of electric power from present fuels by present methods. There is possible improvement along the line of efficiency in this direction, and the public, owing to the fact that we have made certain restrictions on power companies will receive the benefit of these improvements in efficiency.

There are now in the course of construction machines which will improve the B.t.u. efficiency to perhaps 40 per cent for the steam station, and this only goes to show that the trend over a long period of time, for the cost of electric power is down, whereas in all the other fuels it is up. Those things should be borne in mind in deciding whether or not your plant shall become one with electric heat or with other types of fuel.

I just want to relate a story in conclusion, to show you the opposite side of a certain philosophy that has been prevalent to-day. Not long ago a chap down South hung out a shingle "Help Wanted." Before long a darkie shuffled into the office and said, "I see you want some help." The superintendent said, "Yes, we want a fellow to stoke our boiler."

"All right, I want the job," replied the negro.

"Very well, you are engaged; go and report to the foreman of the boiler room."

"But," and the darkie hesitated, "what does this job pay, boss?"

"You go up there and report, and the foreman will pay you what you are worth."

"I am sorry, boss, but I am getting more than that now." (Laughter.)

Now, I am sorry that the furnace manufacturers have not been of the same frame of mind so far as the merits of their furnaces are concerned. Since their comments to-day have been restricted to the praise of their own children, I would like to call on someone familiar with the furnaces of the General Electric Company for melting non-ferrous alloys. I should like to have you call on Mr. Collins, to make a few remarks on that subject.

The President: Before Mr. Collins starts in, I would like to match that story by another one which is indicative of the proper spirit of success. Another firm hung out a sign at the door reading: "Boy wanted." They were up on the fifth floor of a New York loft building. The sign had not been out long before a boy arrived upstairs, bringing the sign with him. He said: "I see you want a boy."

"Yes, we do want a boy, but what did you bring the sign with you for?"

And the applicant replied: "Why, I am the boy." (Laughter.)

Mr. Edgar F. Collins (of the General Electric Company): It is a little late in the day, gentlemen, to begin a long story, and we

have already listened to a number of stories to-day in very great detail concerning a number of furnaces for melting non-ferrous metals. Perhaps, fortunately for you, I did not expect to say anything to-day. I expected to sit here and listen and learn, and so I brought no ammunition along. So I am a little bit handicapped in saying anything about the furnace with which I am more familiar than the other furnaces that have been discussed, and hardly know what to say in a few words to impress it upon you, or make you believe that there is at least one more brass melting furnace that has not been discussed to-day.

I refer to a furnace which we have, in the General Electric Company, been experimenting with, developing, in the laboratory, and of which we have a number running outside the factory in regular production work. The type of furnace is called usually a muffled arc type. However, it is a furnace which is very distinct from the arc type as it is known.

Instead of talking about 70 and 77 per cent power factor arc furnaces, the furnace of which I speak runs normally on 95 per cent power factor, and it is of such a construction that it may be operated single-phase, quarter-phase or three-phase, and on any commercial frequency.

It is capable of giving, in its various sizes—the smallest I might say which I have operated has a capacity of 25 pounds, and running from that size up to 2000 pounds per hour in melting capacity. Due to the fact that I have not with me to-day, as I have said, my moving pictures and slides, I might call your attention to a paper which I delivered a few weeks ago and which has been reprinted in a number of the technical magazines concerning this furnace, giving its data and performances, and pretty well discussing its capability, and if you are interested in these details you can readily find them. It was printed in "The Foundry" beginning with May 15, 1919 issue.

In connection with this furnace I might say that we believe in an automatic control and therefore have a complete control over our power input to the furnace. As a matter of fact, to illustrate the completeness of that control, I will say that it is possible when you shut the furnace down at night to open your power oil switch, and next morning turn that oil switch on with a time clock, and it will pick up and bring itself to temperature without any attention. I am simply using that—not to recommend

it as practice—but to illustrate the type of control that we have arranged.

We also believe in and have arranged equipment so as not to trust to the eye to judge temperature. We use pyrometer control, either automatic control by pyrometer direct, but usually indirectly through the means of an indicating pyrometer, which indicates properly in a brass melting atmosphere. This means that where you have automatic control of your power, and also automatic distribution of your power within your furnace, that you are able

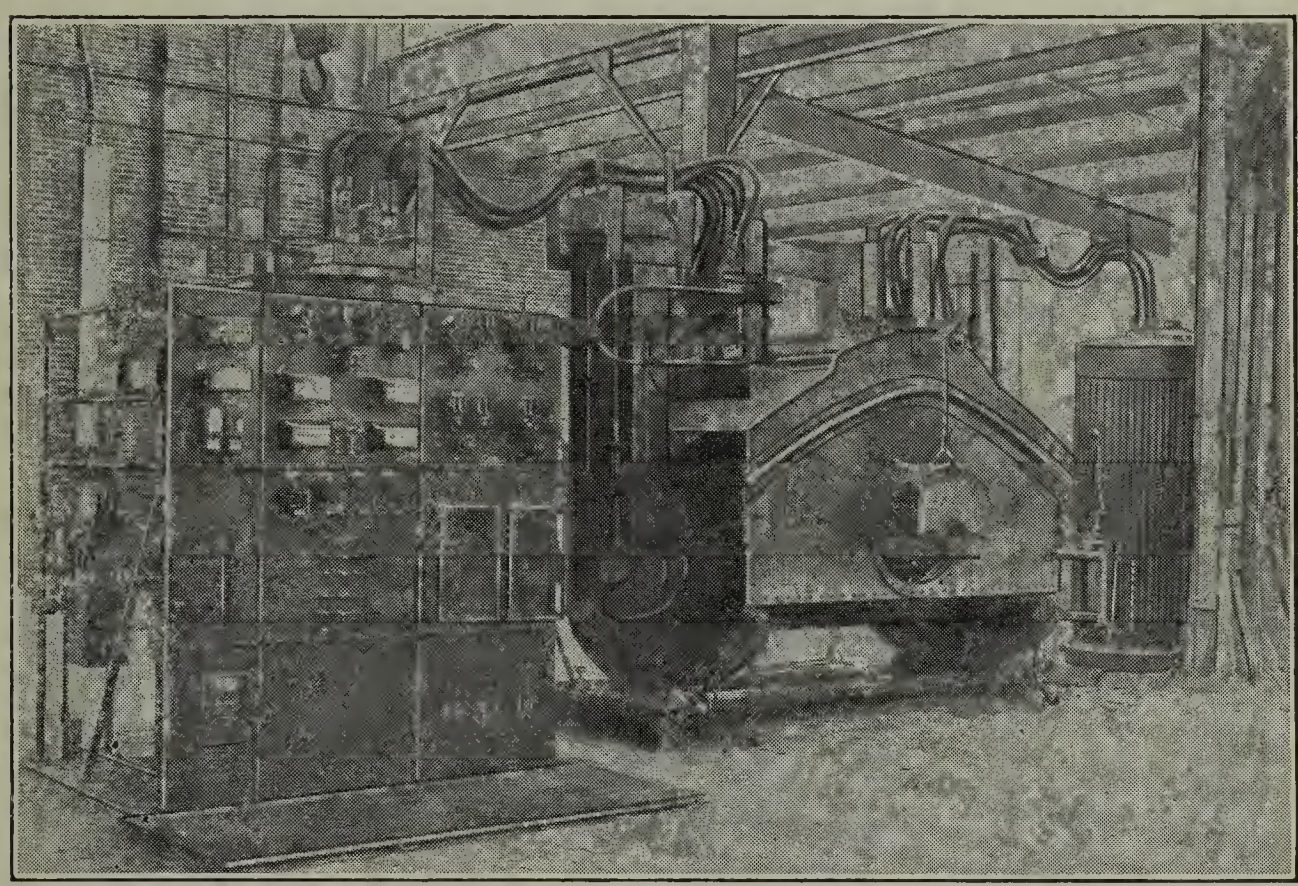

Fig. 3.—Front View of 2250 Pounds per Hour Tilting Type Brass Melting Furnace with Automatic Control Panel and Transformer 400 K. W. Connected Load. U. S. Copper Products Co., Cleveland, Ohio.

to take a given composition of brass and lay out a schedule of performance and calculate your losses very closely from a chart which you will find in the paper to which I alluded.

As regards to metal losses, we all know that metal losses are in a large part dependent upon not only actual composition of the metals which you are melting, but on the manipulation. One of these furnaces which we have in commercial operation, with a capacity of 1500 pounds of red brass per hour, while sold as a brass furnace, has not been operated on brass work but has

been handling a non-ferrous alloy whose base is nickel, and in which certain of the alloys contain as high as 30 per cent spelter, and some of these are being poured at temperatures of 1600 degrees centigrade.

I am told that they are able to put 32 per cent of spelter into this furnace, and form the alloy, pouring at 1600 degrees centigrade, and retain 30 per cent. That is what it has been able to do according to reports of those using it, on the higher temperatures.

Coming down to lower temperatures, we have, with the same type of furnace, been able to refine copper as was stated this morning could be done in certain of these types of furnace, without rabbling or poling, and it therefore offers opportunities to replace the present copper refining furnace where you are melting down your electrolytic plate, and make considerable saving due to the fact you are not contaminating your metal in melting, but are simply melting it down (without rabbling or poling).

We have also taken electrolytic zinc plates and electrolytic copper plates, and have made directly from them in the furnace a brass product which passes the closest inspection. As a matter of fact, samples were sent to a brass wire mill, to be rolled and drawn, and we were unfortunate enough not to get them back because they passed out in their regular product.

Take such things as drop forge trimmings which carry considerable oxide, you may take that material and put it into the furnace and bring it down to pitch in exactly the same condition as the virgin metal. These things, in connection with the use of the furnace, give opportunities for a differential of something like $8 to $10 a ton, I think. Suppose you made your brass from electrolytic plates instead of buying your copper in pig and zinc in bar from the refineries, and made your brass direct, the saving should be attractive.

Coming down to aluminum, it has been found that there are advantages in the melting of aluminum electrically. Much less generation of gases occur in the melting of aluminum in the electric furnace than in the fuel fired furnace, and of course that means that if you are making castings you are getting less porosity, and in making certain aluminum castings that porosity means a great deal.

Take the melting of electrolytic zinc plate and bringing that

down into pig. We have been able to do that with a loss of about 2 per cent for oxidation and dross. I am citing several metals through quite a range of temperature, to show you that this furnace has characteristics decidedly different from the arc furnace, and that we can control the source of our heating, in other words, make the gradient practically anything that we please, and control it exactly as though it was a wire-wound furnace with a rheostat in series.

We transmit a part of the heat to the charge through conduction in the hearth, also a part to the top of bath by reverberatory action. We run with a shallow bath. We don't find it necessary to "rock" this furnace, although we could by adding a contractor or two. We have had no trouble through segregation in any case. We have melted down a pure nickel charge in the furnace (melting pure nickel shot).

Now, I have made a few rambling statements concerning this furnace, simply to have you believe that there is yet one more Electric furnace which has not been gone into in detail here to-day. (Applause.)

The President: We are very much obliged to Mr. Collins for rounding out the symposium as he has done, and I am sorry that we did not have the opportunity to see the pictures and hear the whole story.

Mr. Bragg: I think it ought to be said, in justice to Mr. Collins, that the General Electric Company was appealed to twice, but perhaps the letters never reached Mr. Collins. Out where I come from (Michigan) we know they make the Mazda lamp anyway. I overheard someone say that Mr. Boot's proposition of making the linings in one piece would never work. However, we all know that when Fulton first made his steamboat the farmers on the Hudson River said that it would never work. People said the same thing about Marconi, and about the Wright Brothers, and I am not sure but that we will have linings for electric furnaces in one piece, because I am not sure that it cannot be done. I believe that many of these things which we are directing attention to to-day will be done.

Mr. F. J. Ryan: The majority of papers given this morning that I have listened to have been almost purely commercial. That is, we have come before a body of scientific men with a scientific

instrument and we have talked of the commercial aspect of the equipment. There has been a good deal of that all through the development of the electric furnace industry, both in the steel and in the non-ferrous alloys.

I have been a salesman in the business, and am now supposed to be an engineer in it, and we are connected with the development of Mr. Clamer's work in the Ajax-Wyatt Induction Furnace, and are doing other work in the electric furnace line. But I do feel that there should be a little more explained to the scientific man, with respect to the purchase of electric furnaces, than has been explained this morning.

Mention has been made of a number of different types of linings. In connection with that there has been a statement in nearly every paper that the maximum power should be put in, in the form of the maximum efficiency the linings can take care of it. The difference in fire-brick and the difference in silica brick and other linings mentioned are in a wide range of temperatures. Still, if you were to lay all of the furnace propositions on the table, you would find that the general average of power output was just about the same. Therefore that in many cases is a sales argument, and not an engineering factor.

There is a great deal to be done in refractories, a great deal of investigating to be carried on, to find out what is the maximum top point in consuming without breaking down of electric heat. In many cases we have to have a great deal of radiation, and in other cases we want to cut down radiation. In brass I do not think the refractory comes into it because the temperatures are well below the destroying point of the refractories. But what does come in is the amount of power and the way the power shall come in to best handle the metal. In the steel industry a great many experts have stated that a still bath was better in which to cause reaction, than a moving bath. Whether that will be finally shown in the brass industry or not it is hard to tell, but I do know in Mr. Clamer's furnace, which is an induction furnace, the stirring motion is at the bottom of the furnace while the well at the top is comparatively still, and you certainly get a uniform product out of that furnace.

In the steel furnace, which is analogous, where you have tremendous variations in alloys to be put in, according to the steel

you want to make, most certainly after the slags are taken off and the additions are beginning to be made and have to be made, the real good molder does not bother a whole lot with his bath. He keeps it as well protected as he can without the possibility of contaminating it. The rotating motion or any other is a question of development in a man's own plant.

I believe that the furnace builder to-day should try to conform his furnace to the operation to which it will be put in the conduct of the plant, and not as to how he figures out it will make the best sales argument. The linings will have to be worked out ultimately in practice. But I do recognize that men like Mr. Collins, Mr. Clamer, Dr. Northrup and other men who have given a great deal of time and study and spent a great deal of money on equipments before they have been produced have been sure about it, and I feel that these papers are tremendously interesting, of tremendous benefit, and I do think that if the scientific men to-day would demand that the data that are spoken of are checked up so that we have something to take home with us, to go over and understand, after we are through with it, we will be benefited by its because you as scientific men and practical men may get an idea of something to be gained from it. In fact, we would take away the mystery which has always surrounded it, and we would all get together as, for instance, in accordance with the suggestion this morning about shrinking the brick, and those are suggestions which will bring to you efficiency and practical results.

Mr. E. L. Crosby: I heartily agree with Mr. Ryan in his contention that scientific data should be given in any discussion of this nature. We have tried to adhere to this policy, and have done so to a considerable extent. But I do not agree with him when he states that if the whole matter was laid on the table practically all of the furnaces discussed would show the same rate of power input.

I think it is clear that in the papers presented no two furnaces discussed to-day have anything like the same rate of power. The arc furnace which the Detroit Electric Furnace Company make has a much higher rate of power input than Mr. Bailey mentioned with his furnace, with practically the same arc capacity. And that is a factor in all designs I believe.

The question of reaction in the bath is considerably different

than in the steel business where the refining of steel is carried on by slags and where the addition of alloys takes place. In the brass melting furnace I am not aware that any chemical action occurs in the bath. But agitation prevents the superheating of the metal and secures a thorough mixing of the alloys. I have never heard anyone claim that there was any refining action in the bath which was facilitated by that rocking action.

WOOL SCOURING WASTES[1]

By CHARLES S. PALMER.

Read at the Boston Meeting, June 19, 1919

THE purpose of this paper is to state the object of the work, and to invite the co-operation of all who may be able to assist The Bureau of Chemistry in collecting the materials for the Report implied in this preliminary investigation.

The broad subject of Wool-Scouring Wastes includes the following subdivisions:

1. The recovery and uses of "wool grease."
2. The recovery of potash compounds.
3. The recovery of soap wastes.
4. The recovery of "fertilizer" materials.
5. The perfect clarification of the final effluents, from the standpoints of sanitary sewage purification.

1. WOOL GREASE.—This subject of wool grease attracts our attention at the start, as one which may be described in brief as a matter of simply diabolical ignorance and monumental neglect. The subjects of "wool grease," "wool fat," "wool wax," or "degras," are frequently and variously mentioned, with more or less detail, in many books and papers which cover the general field of the oils, fats, waxes and greases; but there is much inaccuracy and inconsistency, presumably due largely to failure to secure representative and reliable samples. There is no one book in English devoted to the special subject of "wool grease"; and the only known monograph on the subject is the following:

"Das Wollfett," by Ed. Donath and B. M. Margosches, in

[1] Permission Secy. of Agric., U. S.

Ahrens "Sammlung chemischer und chemisch-technischer Vortraege," Vol. VI., pp. 39 to 160 incl. (1901). This monograph is without index or table of contents. It is not usually catalogued under the subject, though some libraries do note the publication under the name of "Donath-and-Margosches." Hence, as most libraries simply catalogue the whole of Ahrens "Sammlung" under that name, and do not attempt to give the contents, either by subject or author, the monograph is as good as lost. Thus it is that I have not yet found on my travels, a single chemist in the United States who even knew of this single unique volume on wool grease. And, even this worthy monograph is now almost twenty years behind the times.

Coming to wool grease itself—which is no "grease" proper, for it contains no glycerine ,and therefore is rather to be regarded as a "wax"—there are *three great groups* of *ingredients* in wool grease. These are roughly:

(*a*) The Esters, ethereal salts of "fatty acids" with cholesterine-like alcohols.
(*b*) The Free Alcohols, cholesterine-like.
(*c*) The Free Acids, "fatty acids," of molecular weight approximating palmitic and stearic, but with some strange associated "lactonic" properties; this is also true of the combined fatty acids in the esters.

It is usually taken for granted that these groups of ingredients exist as esters, free alcohols, and free acids on the fleece of the living sheep; but I have found one chemist who challenges this assumption, believing that most of the wool grease naturally exists as combined esters, and that the showing of the three groups is due to decomposition caused during the extraction. Personally the writer thinks this latter view unfounded; but, even this must be subjected to proof.

There are three great groups of brands of wool grease extracted in America; they are:

1. The "Acid-Cracked" Degras. This is recovered from the suds of the old soap-and-alkali scour; it is essentially similar to the imported "Yorkshire Grease"; it consists mostly of the esters, with free acids, which are those both of the wool grease itself, with

the fatty acids of the soap used in scouring; but with little or no free alcohols.

2. The "Naphtha-Extracted" Degras. This is removed directly from the raw wool by petroleum naphtha; it is supposed to represent the original wool grease as carried on the live sheep; it carries all of the great groups of ingredients—the esters, the free alcohols, and the free acids. It is, in a sense, the only straight wool grease; but is contaminated with slight but offensive foreign impurities from the dirt on the raw wool.

3. The "Centrifugal-Extracted," or "Neutral Degras." This is extracted from the suds of the soap-and-alkali scour, by several well-known makes of centrifugals. This centrifugal degras carries the esters and the free alcohols, but just escapes the burden of the free acids, which are left in the suds as soluble or emulsified soaps, with the added scouring soap. This centrifugal degras usually runs about one or two per cent in free acids, and is therefore much nearer the type of composition usually set for the "lanolines" or "adeps lanae," by the standard dispensatories. This centrifugal degras also removes from the scouring suds the worst ingredients of the wool grease, considered from the sewage standpoint, though the effluent is far from perfect in clarification.

Just here it should be said that in this country, little or no wool grease in any form would ever have been recovered in ordinary times, were it not for the compulsion of sewage and sanitary laws. In most cases, at present, the recovery of wool grease probably falls considerably short of the recovery cost, under ordinary market conditions; recent war prices has shown some marked and natural exceptions.

Uses of Wool Grease.—The uses of wool grease are manifold. When the writer started out to make this survey for the Bureau of Chemistry, I had but half-a-dozen uses on my list; now I have some twenty or more. The uses of wool grease are much as follows:

1. Leather stuffing and dressing.
2. "Compounding," with mineral oils, tallow, rosin oil, etc., as in the making of "lubricating" oils and greases, "wool" oils, etc.
3. Rope and cordage stuffing.
4. "Lanolines," soaps, toilet articles, etc.

5. "Quenching oils," for steel forgings, etc.
6. Many minor uses, as shoe-blacking, varnish, "water-proofing, etc., etc., etc.
7. "Eating," as in making oleo-margarine imitate butter, and in "shortening" for dough in cooking.

The first three uses are said to consume about 90 to 95 per cent—as based on past figures; but the future is liable to show some quite radical changes in the new demands.

In general, we may say that while there is in some lines, as in the leather business, a clear appreciation of the inherent qualities of wool grease, yet, on the whole, most of the makers probably are largely in the dark as to the specific properties and qualities of wool grease as one complex unit. Indeed, the properties of wool grease are contradictory and paradoxical.

Thus degras is called a "grease," yet it is a "wax."

Wool grease is not a "lubricant," yet it makes the ingredients of some lubricants "go together" and stick to metallic surfaces to be lubricated, as nothing else will do.

Wool grease gives both body and viscosity to some oils and mixtures, and yet it also lowers the cold-test.

Wool grease is a water-proof wax, yet it shows the tendency to absorb water as nothing else will.

Wool grease is clear on one point; it is easily the most remarkable "skin-healer" known among the salves.

Now it would be interesting to know just how to separate and refine the main ingredients of wool grease; and it would be still more interesting to know just what are the specific properties of each of the three great groups of ingredients—to say nothing of the details of the properties of each specific ingredient. It would be also interesting to know just how the various wools vary in their content of each of the three groups of ingredients, and as modified by "blood" and "environment." But, simply to state these desires is also to state our complete ignorance on these and a thousand similar matters. Indeed, it may be said that we Twentieth Century chemists know about as much about the real composition, refining, and properties of wool grease as did our fathers know of crude petroleum a hundred years ago.

2. The Recovery of Potash Compounds.—This subject is one that has been often mentioned; but, unfortunately, there are but

few instances of its actual accomplishment. Two instances are known to the writer; one where potash was actually recovered from the waste soap-and-alkali scour, by first skimming off some of the "neutral degras" by centrifugals, and then evaporating and burning off the residues to a water-extractable carbonate; this plant, during the War, took out some ton or so per day of potash; it is not supposed to be working at present. The other instance was one where potash was extracted in attempt, from the first bowl of the "suds" following naphtha-extracted wool; the plant was allowed to go into idleness, perhaps from the troublesome odors developed, and perhaps from lack of economic efficiency. But, enough has been done to blaze the way for later workers, in this line of interesting possibilities.

3. The Recovery of the Suds from the Old Soap-and-Alkali Scour.—This matter has been attacked from the old *acid-cracking* process, and the effluent seems to be in some doubt. This effluent undoubtedly carries some excess acid; and it supposedly also carries some of the "free alcohols" of the wool grease; but some of the best State Board chemists were found to be in the dark as to what is the precise nature of this effluent.

The effluent from the centrifugals is said to be freed from the *excess of the wool grease over the real emulsion;* but there are many cases where the effluent is still far from satisfying the right conditions for perfect sewage clarification; and many chemists are studying the best ways for the further purification of this really troublesome problem. Indeed, the breaking down of such alkaline emulsions—*while still alkaline*—is one of the vexing matters that face us to-day. That the problem is capable of right chemical and physical adjustment can not be doubted; but at present, with some very promising new ways of refining, we still ask for more light.

4. The Recovery of "Fertilizer Materials."—This side problem of the general wool grease question has not received the attention it deserves. The writer can vouch for some remarkably interesting and promising results obtained from the clarification of potash-carrying wastes from "naphtha scour" wool-water. These recoveries, while running low in nitrogen and potash, still carry a per cent of two of each, and when used as local fertilizer they gave unexpected results; though the large content of water would preclude their being transported to any considerable distance. But,

the case is enough to show the great interest that lies hidden in these despised and neglected wastes.

The use of the waste "press-cake" from the acid-cracking process as fertilizer is worth considering. Many of the acid-cracking plants have encouraged the local farmers to cart off this press-cake, for the fertilizing ingredients contained therein; but as the press-cake usually carried about 25 per cent of unrecovered wool grease, and as the farmers seem not to be very enthusiastic about the real value of the press-cake for their land, the matter must be subjected to further work. It ought to be possible to recover the wool grease in this press-cake, and with the better understanding of the many and valuable properties of rightly defined wool grease, and with the better prices that manufacturers can count on in the near future, we may hope to see better work done along the line of using the waste for fertilizer.

5. The Perfect Clarification of the Final Effluents from the Standpoint of Sanitary Sewage Purification.—The conquering of the many points involved in this subject is necessarily tied up with each of the four preceding points; and, as each of these is conquered, it is probable that at the end, there will be but little left for this specific problem. But, at present, this matter of the purification of the final effluent is probably the main problem; for at this writing, we face the approach to the low pre-War prices, together with a temporary glut of the wool grease market; and taken together, the outlook seems anything but inviting. And all this is especially true in view of the gross darkness of immeasurable ignorance that overshadows the people; and, unfortunately, we, the chemists, are "the people."

It is the object of the present movement to collect the facts about the various sides of the wool grease question. We have some acquaintance with the manufacturers' side. We have interviewed many of the middlemen, the dealers and compounders, and at times they are willing to come half-way; though it must be confessed that one of the real difficulties of the whole question is the complication of real facts with what are supposed to be business secrets. We are "long" on vague and general information; we are lamentably "short" on real systematic records of installation, operation, analyses of each stage of operation, exact theory of the "why-and-wherefore" of the many uses, real refining and separating of the main ingredients, exact and reliable bibliography,

exact and reliable engineering records, and origination of special methods for special needs; in short, we simply know that the whole matter stands for just what it has been characterized, a vacant history of colossial ignorance and monumental neglect. It is the expectation that the writer will spend a large part of the rest of his life in dodging the "brickbats" justly due for this elementary and imperfect attempt at gleaning the materials for an honest report; but it is also the fervent hope that this unworthy attempt may serve as the basis for the exact accumulation of something that ultimately may be contemplated with less of shame and regret than is my present confession. If every chemist who knows anything of wool grease and its troubles, will take time to communicate with us at the Bureau of Chemistry, we may succeed in starting something that will ultimately clear up this neglected but promising subject; for, literally, there are "millions in it,"—not to mention the certainty of a new field of rich, surprising, and marvelously interesting chemistry.

THE MANUFACTURE OF CASTOR OIL.*

By J. H. SHRADER

Read at the Boston Meeting, June 20, 1919

BEFORE the war castor oil was one of the minor though regularly recognized industrial oils which had achieved a place in the industrial world of a highly specialized character. Its technology though similar in some respects to that of the large oil staples differs quite materially in others. Only about half a dozen firms in this country have made much effort at manufacturing the oil, and of these only about four were specialists in its production on a large scale. However, its use has steadily increased. In the fiscal year 1909-1910 the United States imported about 16,700 tons, or 726,000 bushels, of beans, while in 1915-16 the imports climbed to 24,700 tons, or 1,072,000 bushels.

The advent of the war was the stimulating cause to unprecedented consumption of castor oil. This was for lubricating airplane engines. For such a purpose it is necessary that the oil have a minimum of free fatty acid. Commercial grades of oil meeting this low acid requirement have been low in color. This last property at first led to the assumption that a satisfactory castor oil lubricant should be colorless, but tests in engines have refuted this. All that seems to be necessary is to have a pure oil of low acidity, not over 1.5 per cent acid, figured as oleic acid.

The method of obtaining the oil in America and in Europe has been to heat the beans gently to about 110° F., without breaking the seed coat nor otherwise milling nor tempering the beans. If the seed coat is broken and the kernel exposed to the air, the exceedingly active lipase present quickly runs up the acidity to unacceptable amounts. Therefore, only the whole beans, slightly

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warmed, are pressed. This operation is carried out in so-called cage presses. These are different from ordinary cotton-seed presses in that while the latter are provided with plates and require the oleaginous material to be wrapped in cloths, the cage is a perforated iron cylinder or box, open at both ends, allowing the ram to enter and press the charge against a block in the opposite end, while the oil is discharged through the perforations in the walls. Iron plates, fitting the "cage" snugly, are laid in as the beans are introduced and serve to facilitate drainage and divide the contents into cakes. When the cage is full, it is placed between the ram and the block and the pressure is applied. Inasmuch as castor beans contain from 45 to 50 per cent of oil it follows that much oil is obtained by this cold pressure. In fact, present practice calls for about three-fourths of the oil, or 15.6 pounds as so-called No. 1 oil, about 4.1 pounds as No. 3 oil, and 25.5 pounds of pomace.

The No. 1 oil as it comes from the press is brownish gray in color, due to a fine cloud in suspension consisting of more or less moisture from the beans and some meal. The oil is first heated to remove this moisture and then treated with fuller's earth and bleaching carbon. After half an hour's agitation at about 190° F., it is filtered by pumping through an ordinary plate and frame filter press, and is then ready for market. It is not refined in the ordinary sense, as refiners use the word to designate the alkali treatment to remove free fatty acids. What refining it does get is more of a bleaching and filtering operation.

The cake, containing about 15 per cent of oil, is removed from the cage, ground and sent to the extraction house. Here it is extracted by some volatile solvent, such as gasoline or benzol. Both stationary and rotary extractors are used with attendant advantages and disadvantages to each. But the rotary extractor seems to give the better satisfaction. The resulting extracted oil is usually high in acid, due to the exposure of the ground cake to the air between the time of discharging from the cage and the time the charge in the extractor is covered with the solvent. Doubtless, air exposure and consequent acidity could be cut down to a minimum if this so-called No. 3 oil found no market. But since it is more or less readily absorbed for various industrial uses, the manufacturers exercise little care to keep down the acidity.

Naturally this extracted oil is also darker in color than the No.

1 cold-pressed oil. It varies from a brown to a green, apparently according to the solvent used and the treatment the oil has received in freeing it of the solvent. Different solvents seem to have selective properties in extracting the pigments. Gasoline gives a straw-colored oil, benzol a green-colored oil, while methyl ethyl ketone gives an oil red on fresh extraction but which slowly turns to a dirty greenish brown on standing exposed to the air. It is noticeable that most of this color resides in the seed coats. Extraction of decorticated beans with benzol gives a very light-colored oil, while extraction of the removed seed coats gives a highly colored one. In the laboratory we have made an extracted No. 3 oil of a straw color no darker than much of the No. 1 cold-pressed oil regularly found on the market, by extracting fresh whole beans with benzol. It is necessary to use great care in boiling off the solvents, due to the fact that excessive heating darkens the oil. In fact, heating No. 1 castor oil at 90° C. for three-quarters of an hour quite materially darkens it. Consequently, boiling off of the solvent should occur under vacuum.

The advantages of extracting all the oil by solvents instead of the combined expelling and extracting practice are that the oil would be obtained entirely as No. 1 oil with no attendant No. 3 oil, the cost of the operation would be minimized due to only the one handling involved, while the taste factor would not be seriously affected for the simple reason that castor oil can be freed from such foreign flavors in a deodorizer the same as any other oil.

The No. 3 oil can be refined down to a very low acidity by an alkali treatment which is complicated, however, by the ready solubility of the soap stock in the oil. Due to the high viscosity of this oil, rendered increasingly so by the amounts of dissolved soap, it is difficult to wash out all of this soap on account of its ready emulsibility. A salt brine, however, effectually breaks up almost any emulsion which may be formed. Further treatment consists only in filtering the oil through enough fuller's earth to cover the cloths. Having obtained the clear dark oil, the utmost endeavor has not been successful in bleaching it. The solvent treatment seems to introduce a color which becomes fixed and resists ordinary bleaching methods.

It is evident that this resistance to bleaching is due to the twofold trouble of having extracted certain coloring matters from the

seed coats, but mainly to the more or less indifferent treatment accorded to the pomace and the No. 3 oil. Using ordinary care in handling, a very green castor oil made by expelling castor beans in the hull has been successfully bleached down to a straw color. Moreover, greenish oil extracted from the whole beans can be bleached readily to an almost white oil.

Such, in a few words, is the practice ordinarily followed in castor oil manufacture. It is seen that the procedure is fairly simple. When the suggestion was made to use expellers on the beans many oil men stated that it has been previously tried and could not be continued successfully. The objections seemed to rest in the first place on the ground that the oil would not remain clear but would precipitate foots on standing, and in the second place that the hard siliceous seed coat would so cut the cone of the expeller that the wear on the machines would be prohibitive. This was tried out and on the favorable outcome the Government erected probably the largest castor oil mill in the world at Gainesville, Fla., installing fifteen expellers.

These machines have been running in lots of from six to the full capacity of fifteen since the first week in November, 1918, each machine being in continuous operation probably about one-third of the time, but during April and May the whole plant has operated at its estimated capacity. The wear on the cones has been even less than in the case of pressing peanuts. Out of a linear movement of two and a half inches for the cones to be moved in to take up the wear, they have in all this time been tightened up only one-half inch. At the same time the machines are yielding more pounds of No. 1 oil per bushel than the regularly operated cage presses. Since each expeller in ordinary every-day practice handles eight hundred pounds of beans per hour (and more if pushed), with two men operating all fifteen, it follows that the cost of factory operation is at a minimum.

Some of the earlier oil has deposited a slight cloud on long standing, but inasmuch as oil made by cages often does the same, this fault can hardly be laid to the machine.

The extraction equipment of the Gainesville plant consists of a battery of stationary extractors and originally gave much trouble before they were made to work satisfactorily. It was this extraction plant which has until recently held up the capacity of the

expeller room due to the obvious fact that the castor cake from the expellers must not be allowed to accumulate ahead of the extractors; otherwise the oil content of the pomace would be ruined, due to the lipolytic action of the contained enzyme. It was not until April that the difficulties of adapting stationary extractors to castor pomace extraction were overcome, whereupon the whole plant was put on a balanced basis and was enabled to operate at capacity. Since then during the months of April and May and the early part of June it has been running to capacity, approximating 13,000 bushels of beans in a week of six days with the press room operating on a 7-8-hour expelling day, which reduces to about 18 to 20 bushels, or 828 to 920 pounds per hour per expeller.

There follows a table showing a comparison between the properties of expeller No. 1 oil versus hydraulic pressed No. 1 oil. In both cases the figures represent analyses taken from records of the Bureau of Aircraft Production, extending over the whole period that the service has been purchasing castor oil for its airplane lubrication. In the case of hydraulic pressed oil the samples were taken from all the leading manufacturers and covered a period of about one year, while the expeller figures were taken from seven batches manufactured since the plant began to operate in November.

Castor oil is difficult to work with in comparison with the other oils on account of its viscosity, emulsibility, sensitiveness to heat and light, and readiness to become acid. One-half hour's heating at 190° F. noticeably darkens it. It cannot be held overnight unless previously dried without an increase in acidity of several tenths per cent.

It is thus evident that as result of the Government's study of the technology of castor oil manufacture the contributions to our knowledge of the process embrace in the first place the fact that there are strong probabilities of the economical manufacture of castor oil by the solvent process alone. This, however, has only been worked out on a laboratory scale. The other step marking an advance is the demonstration on large scale factory operation and extending over eight months that expellers can be used economically and satisfactorily for castor oil manufacture. Most of the work leading up to these developments has been done in the Bureau of Plant Industry, but credit is to be attached to the

TABLE

	Hydraulic Cage Expressed No. 1 Oil.		Expeller No. 1 Oil.		Expeller Refined No. 1 Oil.	Expeller Extracted and Refined No. 3 Oil.
		Average		Average		
Specific gravity (15°.6 C.)	0.961–0.965	0.9626	0.961–0.962	0.9613	0.9643	0.960
Acidity (per cent)	0.45 –1.6	1.22	0.85 –1.46	1.17	.....	.....
Iodine number	83.0 –87.5	85.6	80.8 –86.1	84.2	87	.....
Saponification number	176.3 –188	182.5	178 –182	179.6	180.9	.....
Unsaponifiable matter	0.21 –0.78	0.33%	0.20 –0.30	0.26%	.....	.....
Flash point	513°–570° F.	535° F.	524° –527° F.	525° F.	555° F.	555° F.
Viscosity	93 –112	97.1	.....	....	100–101	100

untiring energies of Mr. D. C. Gillett of the Gillett Oil Company, who is operating the plant for the Government, and to his Superintendent, Mr. E. M. Hinson, who so efficiently worked out the factory details and installed the equipment during the stress of war times. The Toledo Seed and Oil Company also contributed materially to the general success of the undertaking.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of Drug, Poisonous and Oil Plant Investigations.

THE FLASH AND BURNING POINTS OF GASOLINE-KEROSENE MIXTURES

By JAMES T. ROBSON and JAMES R. WITHROW

Read at the Boston Meeting, June 1919

The results of this work indicate:

1. The profound effect upon the flash and burning point of kerosene and therefore the fire and explosion hazard of the smallest percentages of gasoline or similar volatile petroleum fractions added to the kerosene.

2. Gasoline cannot safely be permitted in kerosene.

3. The early records of the influence of light petroleum distillates upon burning oils were based upon fractions radically different in properties from similarly named products of modern refining.

4. The main original need for State Flash Point laws has ceased. Nevertheless, public safety still requires their enforcement.

6. The Foster closed cup flash determination permits the presence of much lighter petroleum distillates than the Cleveland open cup method.

6. The gasoline and other light petroleum fractions are found to be miscible instantaneously with kerosene if intimately mixed. It is concluded that stratification in large tanks is merely due to insufficient mixing or lack of time for diffusion.

7. While ordinary kerosene of commerce extinguishes a burning match, the addition of gasoline to the extent of 1% may give a flash. 3 to 5% may give violent flashing and 7½% may inflame at once. Any of these would have given explosions if confined.

8. The relation is established between flash and burning point and percentage of volatile petroleum fractions admixed with kerosene. Working conditions are given minutely, to establish the comparative dependability of the final values for future cases of comparison. Distillation and gravity characteristics of the fractions used are recorded.

Because of our own inability to obtain material assistance from the literature on the influence of the addition of gasoline to kerosene with repect to the explosion hazard after the kerosene was marketed, it seemed desirable to publish portions of the work made necessary by this scanty literature.

Fatal Results from Gasoline Contaminated Kerosene.

One or several deaths appear to have resulted from explosions in the use of kerosene admitted to have been marketed in Ohio by an oil refiner. It is also admitted that an employee of the refiner inadvertently pumped gasoline into a kerosene storage tank and also that kerosene was subsequently sold from this tank batch. It was claimed by the plaintiff that the kerosene causing fatal explosions, could be directly traced to this contaminated kerosene storage. It is claimed by employees of the refiner that a gallon sample was drawn off of the contaminated kerosene tank and its flashing properties tested and found "safe."

It would probably have to be admitted that a draw off of one gallon would not clear the uncontaminated kerosene from the draw-off line and as a result the "safe" flash test would not reveal the true character of the tank contents.

In this same connection also it was claimed by the plaintiff that stratification probably existed in the tank anyway and therefore a sample withdrawn from the bottom of the tank would inevitably test "safe" in flash point. It was also claimed that dispensing from said tank would soon reach a highly dangerous zone because richer in gasoline.

No exact evidence was available as to the amount of kerosene originally in the tank or the amount of gasoline pumped into it or the amount of the mixture resulting. It would probably have to be admitted, however, that there was more than 2% gasoline as a minimum admixed with the kerosene or any lot sold therefrom if admixture were complete. No actual sample of the mixture appears to have been preserved by either side. The samples causing the explosions were destroyed thereby.

Early Work on Explosion Hazards.

In 1861 Allen (Smithsonian Reports 1861, p. 330) reported on the "Explosibility of Coal Oil" an investigation instigated by the

Rhode Island Mutual Fire Insurance Company to study various "coal oils." Both petroleum and coal tar products were included under "coal oil." That gasoline was then a drug on the market was pointed out as was the artificial production of kerosene with a kerosene gravity by judicious mixtures of higher and lower fractions than the kerosene fraction proper.

Allen made flash-point determinations in open cups floating in water at various temperatures. This seems to us a cumbersome manipulation as compared with our simple direct heated or water-bath heated devices. He did not know the amount of "adulteration," however.

K. v. Weise in "Wagner's Chemische Technologie," 1871, p. 865, with the Open Cup Method found:

	Sp. Gr.	Flash Point	Burning Point
Petroleum	0.805	30°	43°
Petroleum + ½% Naphtha..	0.710	25°	40°
Petroleum + 1% Naphtha...	0.710	22°	32°
Petroleum + 3% Naphtha...	0.710	20°	29°

This work is by far the most complete along this line in the literature. The oils used, however, are quite different from those with which we are concerned. The closest to our conditions are these:

	Flash Point	Burning Point
Petroleum 0.806	55°	70°
Petroleum + 2% Naphtha.....	45°	60°
Petroleum + 4% Naphtha.....	24°	55°
Petroleum + 10% Naphtha.....	20°	32°

There was no closed cup work. The author states that for the determination of the naphtha content, neither the flash point method or fractional distillation is satisfactory.

In 1887 Crew (Treatise on Petroleum 1887, Philadelphia, Henry C. Baird and Co., p. 395) pointed out adulteration of kerosene with dangerous low-boiling fractions and presented a simple "saucer" test to show whether or not a given oil was dangerous for use in lamps.

Crew quotes experiments of Dr. C. B. White of New Orleans resulting as follows:

	Flash Point	Burning Point
Oil alone.....	118° F.	135° F.
Oil with 1% "Benzene," 65° Bé....	112° F.	129° F.
Oil with 3% "Benzene," 65° Bé....	103° F.	123° F.
Oil with 5% "Benzene," 65° Bé....	96° F.	116° F.
Oil with 10% "Benzene," 65° Bé....	83° F.	102° F.
Oil with 1% "Benzene," 72° Bé....	107° F.	133° F.
Oil with 5% "Benzene," 72° Bé....	70° F.	105° F.

Allen's Commercial Organic Analysis, 4th Ed., Blakiston, Philadelphia, 1914, p. 120, states that "Dr. B. W. White" using the "open test" found that with

Oil which originally flashes at 113° F.
1% naphtha reduced flash point to 103° F.
2% naphtha reduced flash point to 92° F.
5% naphtha reduced flash point to 83° F.
10% naphtha reduced flash point to 59° F.
20% naphtha reduced flash point to 40° F.

No further information is given.

It is not evident whether this is the same Dr. White as referred to by Crew.

These results correspond only approximately with ours. They are upon the older type of low flash kerosene and with uncertain procedure. They are interesting, however, as tending to show the influence of definite admixture on an oil of know flash point. No modern case has been found by us where there is a clear correlation between definite admixtures of characterized products and the flash and burning test with prescription of conditions of test.

Steingraber, Chem. Zeit. Oesterr, 1900, p. 589-99, Jr. Soc. Chem. Ind., 1901, p. 352, tried to determine how far the properties of "illuminating" fractions of oil were affected by benzine mixtures. He used 21° C. flash oil as standard and added various amounts of benzine and higher fractions. His results showed that only benzines boiling below 100° C. have strong influence on flash. Additions of higher boiling benzines have little effect. 21° C. (or

70° F.) is too low as a flash oil to take as a standard to determine effect of benzine on flash. With 110°-120° F. flash oils as standards,

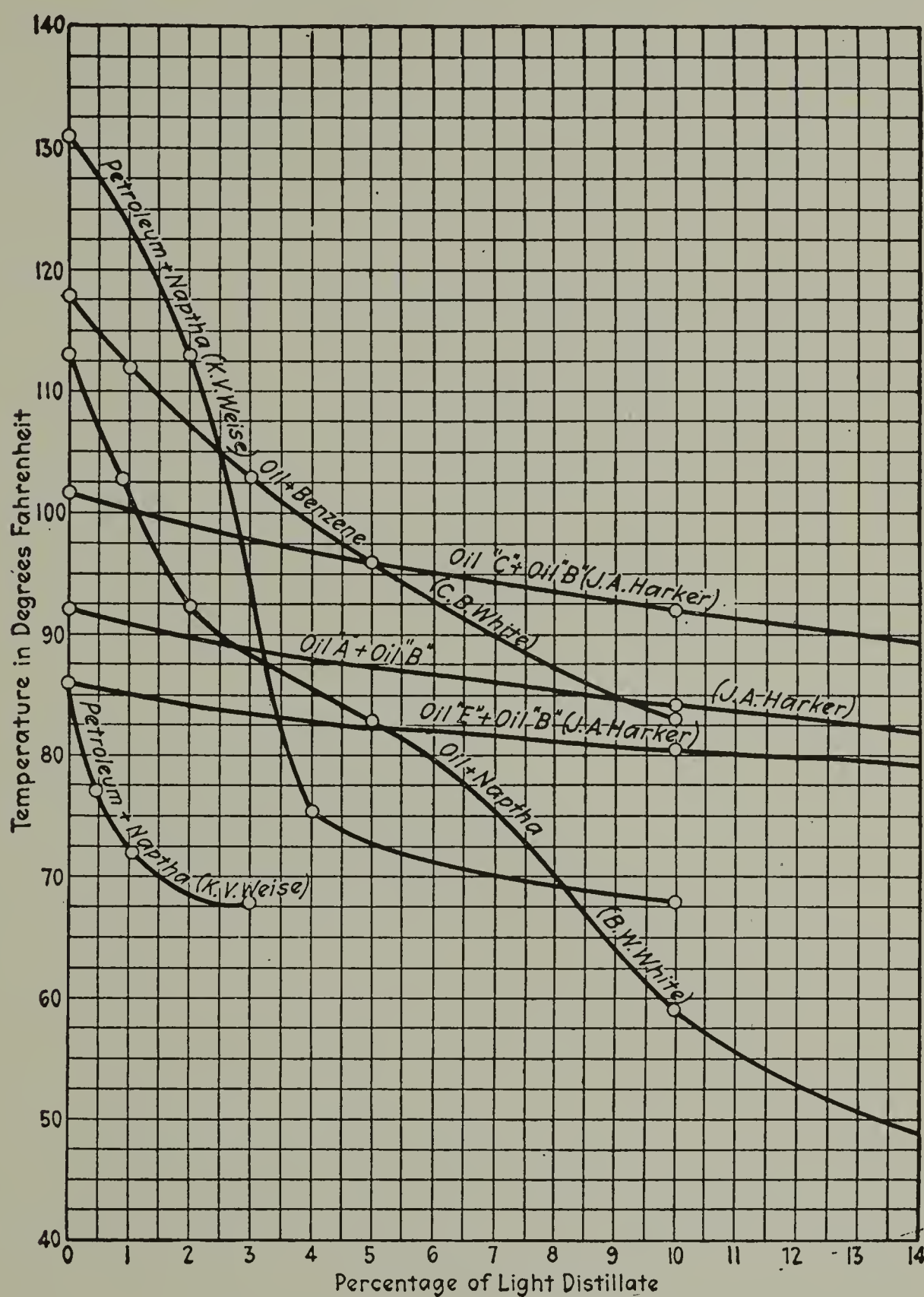

FIG. 1.—Flash Point Curve Early Workers.

effect of higher boiling benzines are somewhat different than found by Steingraber.

H. C. Sherman, T. T. Gray and H. A. Hammerschlag, Jour.

Ind. and Eng. Chem., vol. 1, 1909, p. 13, compared the calculated and determined viscosities and flashing and burning points of oil mixtures. This work shows that the calculated flash point is not the same as the actual. The work was not on kerosene, however.

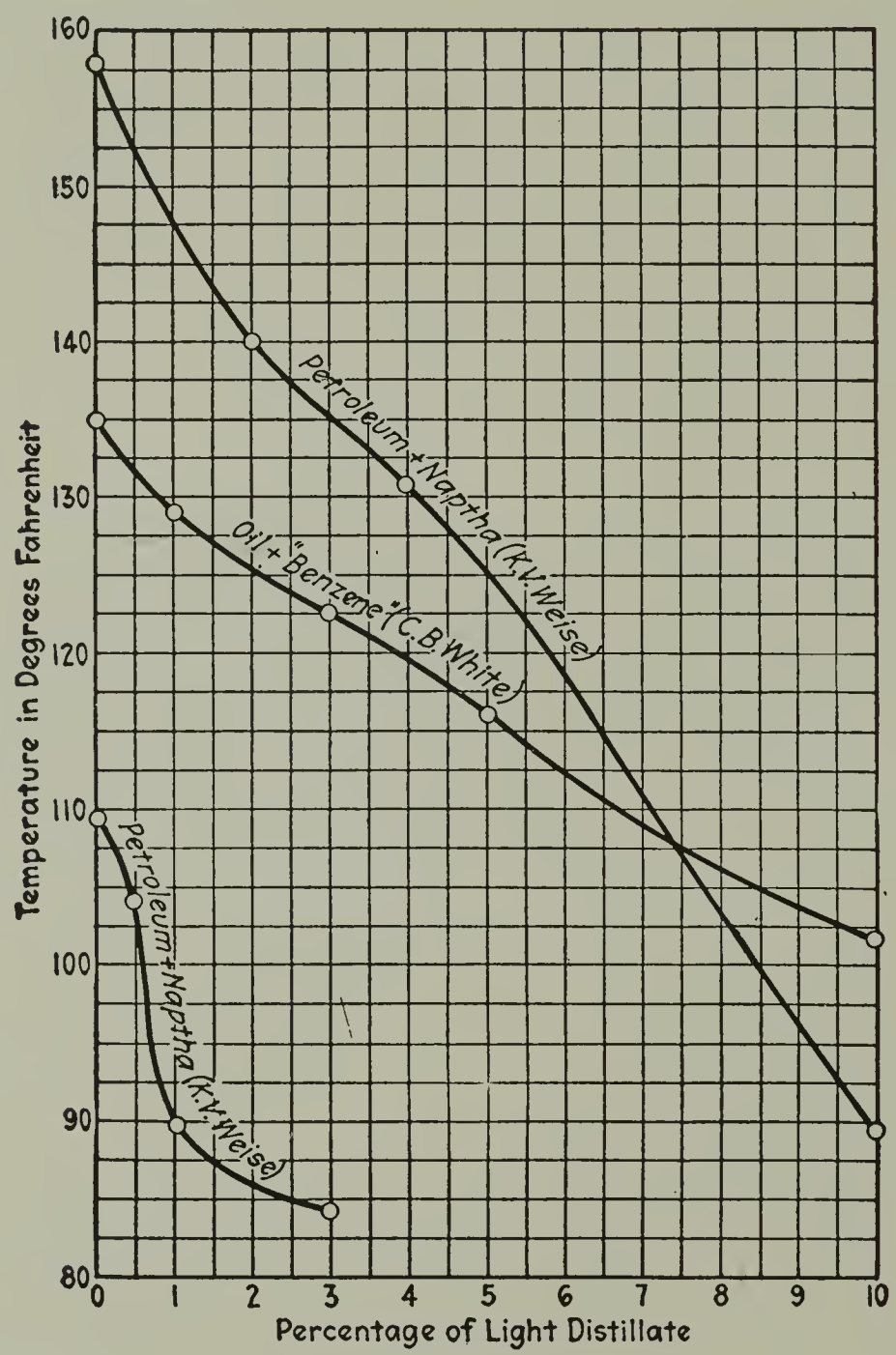

FIG. 2.—Burning Point Curves Early Workers.

J. A. Harker and W. F. Higgins on the Methods and Apparatus Used in Petroleum Testing, Collected Researches, Nat. Phys. Lab. vol. 8, 1912, p. 38, give a method for calculating flash points of different mixtures of oils. No method is given of identifying their oils.

Intervals (10%) of mixture used are so large that is not

justifiable to determine flash point for any intervening mixture (say 92% or 97%).

Harker's work intends to give a method of determining the flash point when the composition is known; our work will give approximately the composition of the mixture from a determination of the flash point and interpreting on the basis of the distillation curves which identify our oils. Curves representing the values recorded by these earlier workers appear on Plates No. 1 and 2.

Factors Influencing Fire Hazards of Gasoline and Kerosene.

Strictly speaking, the flash point by itself does not determine the fire hazard of any substance. The factors which also influence fire hazard are:

(*a*) Volatility.
(*b*) Boiling Point.
(*c*) Vapor Pressure.
(*d*) Vapor Density.
(*e*) Diffusibility and tendency of vapors to travel.
(*f*) Explosive limits in air.
(*g*) Tendency to chemical change.
(*h*) Quantity of heat liberated per unit of volume.
(*i*) Temperature of flame.
(*j*) Corrosive action.
(*k*) Behavior toward water before and after ignition.
(*l*) Tendency of substance to leak.
(*m*) Prolonged heating effect.

Kerosene in tropical climate gives lower "flash" than same oil in temperate climate. The trouble is due primarily to accumulation of vapors caused by continued high temperature and secondarily in discharging or moving oil by vapors disengaged on pouring and shaking.

It is well known that cold kerosene of good legal quality will not take fire when light is applied, nor will the supernatant vapor inflame. The "burning test," fire test—i.e., temperature at which oil permanently inflames—is sometimes taken as a test of burning or firing value but is not strictly reliable since *oils, spilled in a thin*

flow will ignite instantly on approach of a flame, even when the burning point is considerably higher than the flash point.

It is also well known that with refined burning oil no inflammable or explosive mixture could be formed, even in the absence of ventilation, up to 70° F. At temperatures much above 80° F. and with no ventilation, such an atmosphere could be produced with most oil.

Early Flash Point Laws and Present Reversed Status of Gasoline and Kerosene Production.

It would have to be admitted that the presence of lighter or gasoline fractions in kerosene has long ceased to be profitable to the refiner. Hence, as an evil it has needed little attention in recent times.

If commercial gasoline of any gravity is accidently pumped into or, by faulty valving or otherwise, gets into a kerosene fractions storage its detection is quite simple by the flash test. Simple consideration indicate, however, that this can be no quantitive indication of the amount of such contamination except the "Flash Point" determination be calibrated with reference to this particular kind of occurrence. Individual oil companies or chemists doubtless have felt the need for such a correlation and perhaps have made it. Few of these results have gotten into the literature. From year to year we have had cases arise which raised the question: how much gasoline does this particular contamination represent? Recently the question arose again under the circumstances already mentioned which made a partial answer to the general question necessary and the results obtained with our set of conditions are here recorded.

In the earlier period of petroleum refining, kerosene or "burning oil" was the valuable light product or early distillate. At that time it was a temptation to producers to put into kerosene all the traffic would stand of lower boiling (gasoline) fractions, together with the maximum of higher boiling fractions next above the burning oil, to balance the lighter gravity of the gasoline fraction. This virtually amounted to a physical synthesis of kerosene by mixing with each other the next lower and higher fractions. This was a perfectly justifiable procedure, if a safe one, to meet commercial demands in the days that developed "crocking" for burning oil formation. "Gravity," however, was not the sole consideration.

There was a safety limit which was important because the consumer in the homes of the land might be made the victim of unnecessary fire hazard, through refiners' carelessness or unscrupulousness in this connection. Many tragedies resulted and legislation put a curb to syntheses of this kind by setting legal limits in a modified practical safety-test in the Flash Point Laws.

Of the law requirements (Gill's "Oil Analysis," 3rd Ed., J. B. Lippencott, Philadelphia, p. 131; Stillman's "Engineering Chemistry," Chemical Publishing Co., Easton, Pa., 1916, p. 450) in 32 states, 19 fix a minimum Flash Point of 100° F. to 126° F. The other 12 states make a minimum "Burning Point" instead of Flash Point requirement. This Burning Point runs from 110° to 150° F. in the states making the requirements. Four states set both a minimum Flash and Burning Test and 16 no Burning Point test at all. Those state laws specified in all except 8 cases the form of test whether in "open" or "closed" apparatus. In only four cases was "open" testing permitted. In all other cases a closed tester was prescribed, thus closely simulating lamp or confined conditions, and the specific instrument was named such as the Tagliabue or Foster. From the results herein reported it will be seen that the closed cup of the Foster type may permit the presence of much more gasoline in a burning oil than does the open cup test for the same flash point.

In that early period of the petroleum refining industry gasoline was a drug on the market. All the art of sales was directed to the creation of an outlet. The public had to be protected, therefore, against unscrupulous addition of gasoline to kerosene to increase production volume of the latter. Now the situation is reversed. The advent of the hydrocarbon or internal combustion engine about 1898 has created ever increasing demands for the gasoline fraction so that the kerosene demand by comparison stands still. Now as a result, the refiner puts everything into gasoline that the traffic will stand. This is as it should be, if understood. Consequently, the cheaper kerosene fraction is stripped as lean as possible of volatiles to raise the volume of the gasoline fraction. This puts so much of the front end of kerosene into gasoline that, of course, the gasoline is made heavier in gravity as is the kerosene. This greatly raises the flash and burning point of the kerosene because the more volatile portion was cut off to add to gasoline. This is so effectively done in wideawake refineries that the State Flash Point

laws are almost a dead letter. They, nevertheless, are necessary, however, because there are still a few poorly equipped or carelessly operated refineries. Occasionally errors or accidental contamination of kerosene storage will occur and the plant manager refuses to re-strip the mixture to save expense and instead works it off on the trade. We seem to meet occasionally just this situation in Ohio State Oil Inspection and the protection to the public in those cases justifies the continuance of this state activity. In addition, there are the mistakes of delivery and petty storage-filling between wholesaler, retailer and eventual delivery to consumer. These, while not common, are much more common than refiner's mistakes, but are depressed in number by vigorous legal inspection and law enforcement particularly in rural sections.

When the State Oil Inspector's office picks up offenders under the Ohio law it at times can trace a somewhat connected series of infractions indicating a bad lot of kerosene, and at times traceable to the refinery. In referring such matters to this laboratory the question is sometimes asked about the extent of gasoline contamination. It is not necessary to cite cases except to state that confirmation of the field inspectors' test have at times been so good as to have the product pop-off on lighting the taper in the Foster closed cup. (The legal test instrument in Ohio.) The taper is lighted customarily at 90° F., and the Ohio minimum flash point for kerosene is 120° F. Such a product is highly dangerous as a kerosene.

For this portion of the public welfare and safety, the State Oil Inspection laws are still an important factor. Careful, honest dealers and refiners have no quarrel with these laws.

The Flash and Burning Point Tests.

There are some factors which must be clearly understood when dealing with flash-point determination. The substances—kerosene and gasoline—themselves are not chemical compounds but mixtures of hydrocarbons. "Kerosene" is a trade name. It is also called "coal-oil" and "Illuminating oil." Industrially it is understood to be a mixture of hydrocarbons "entirely" free from gasoline and naphtha on the one hand and from heavy hydrocarbons belonging to gas oil and lubricating oil on the other. This (kerosene) mixture is only supposed to be moderately soluble in alcohol but miscible

in all proportions with ether, chloroform, "benzene," petroleum spirit, volatile and fixed oils except castor oil.

Gasoline is a mixture of the lower series of hydrocarbons. It is lower in boiling point and lighter in gravity than kerosene. It includes all of them that are not "wild" or which will stay in a reasonably corked container and running as heavy in gravity as motor vehicles can start and navigate under. It usually includes all the old materials called variously petroleum spirit, petrol, benzine, etc. Formerly, that which distilled below 150° C. was "spirit" or gasoline, 150-270° C. was kerosene and 270° C. up was heavy oils. This was only conventional. Refineries ran largely on gravity. The consumer became acquainted with a specific gravity test. It was easy to perform and the refiner cut his fractions at various gravities in order to have his cuts average some other gravity required in the trade.

The flash point is the lowest temperature to which the oil need be heated under a fixed set of conditions to give off vapors in sufficient quantity when mixed with air to explode upon the approach of a flame.

The burning point or "fire test" is the lowest temperature at which oil will give off sufficient vapors to burn continuously when ignited.

The Flash Point and Burning Point Tests are arbitrary. They are not measures of rigorous constants yet they are capable of much refinement. They are accurate determinations of the practical effects of complex factors. For these reasons the values as determined are susceptible to influence from many sources among which may be mentioned:

1. Barometric Pressure.
2. Nature of bath as a source of heat.
3. Design of oil cup.
4. Features of thermometer.
5. Rate of heating.
6. Effect of prolonged heating or cooling.
7. Manipulation of test. (Manner flame is applied for flashing, etc.)
8. Room temperature and conditions.
9. Initial temperature of oil being tested.
10. Influence of water presence.
11. Personality of operator.

Even the determination of the flash point of a pure hydrocarbon (from the mixture whose vapor pressure effect is really the matter at issue) would be influenced by most of these factors.

The aim was a practical test and experience has forced precautions and developed refinements. Burrell and Boyd (U. S. Bureau of Mines Tech. Paper 117) have pointed out the relation between vapor pressure and explosiveness of air gasoline mixtures as related to sewer atmosphere. No one appears to have correlated vapor pressures and explosion and ignition studies—of vapor—air mixtures in connection with flash point determinations. The machines in use are accurate enough for short cut results and are certainly practical in that they simulate burning lamp conditions.

EXPERIMENTAL.

Character of the Miscibility of Gasoline-Kerosene Fractions.

Among the questions raised in connection with the litigation referred to were (1) the nature or degree of miscibility of gasoline and kerosene fractions in each other and (2) the influence upon the flashing properties of a kerosene in the event of miscibility proceeding at a practically instantaneous rate.

It is well known that petroleum fractions are miscible in one another. It cannot, therefore, be assumed that this has no limit in the case of any two restricted fractions in the absence of whole series of hydrocarbons of the original petroleum. Experiment upon various "gasolines" and a sample of kerosene using every precaution to prevent mechanical mixing, practically always resulted, in the laboratory, in a product with the same flash and burning point as a thoroughly mixed sample. This appeared to be independent of the time of contact, position of admission to the kerosene, depth of kerosene layer (up to one foot); portion of layer from which test sample was withdrawn, and the relative proportions used. This completely answers the ultimate degree of miscibility of the gasoline and kerosene fractions available for our experiments. The results also appear to answer the question of the nature of miscibility, i.e., it appears to be instantaneous. As these were laboratory experiments, they cannot be offered as conclusive, for they are subject

to the criticism that an apparently instantaneous time factor in the laboratory may be quite a different matter in the plant where great volumes and depths of tank are factors modifying the situation. Also it is well known to refiners of light boiling oils such as petroleum and coal tar hydrocarbons that mixing or blending in tanks even as small as 10′ x 12′ does not proceed automatically upon mere addition, but air agitation is necessary to insure completeness of mixing. We possess no exact knowledge on this subject and carried out no experiments in view of the trouble and expense attached thereto and because of the existence of definite experience that miscibility has a real time factor in large scale operations. As an illustration, petroleum distillate tanks have been known to test 45° Bé. at the bottom, 47° at middle and 49° at top. Again, pumping a light gravity oil into a 250-barrel tank containing heavier oil, inlet at bottom, showed when 240 barrels were in tank, 58° Bé. at bottom, 61° at middle and 68° at top; quantities used not known.

The Inflammability of Gasoline-Kerosene Mixtures.

The following results indicate the effect upon the flash and burning behavior of kerosene used by admixtures of gasoline at ordinary temperature. These experiments were carried out in an ordinary graniteware cup, using 100 cc. of oil each time. In these experiments, "low test" gasoline was used. The kerosene was measured in a 100-cc. graduate, and the gasoline up through 3% was measured in pipettes. From 5% on the gasoline was measured in the cylinder. With 100% kerosene a lighted match when applied quickly or very slowly was extinguished. With 99% kerosene and 1% gasoline the match flashed when added, but was extinguished when immersed in oil. With 3% gasoline and 97% kerosene, there was a flash more noticeable than the 2% mixture but the match was also extinguished when immersed in the oil. With 5% gasoline and 95% kerosene the oil flashed violently but did not burn. With 7½% gasoline and 92½% kerosene the oil flashed with a puff and readily burned when the lighted match *touched* it. With 12½% gasoline and 87½% kerosene the oil flashed with a loud puff and readily burned when the lighted match *approached* it.

Flash and Burning Points of Kerosene-Gasoline Mixtures.

Since so little is said in the literature about the effects of highly volatile petroleum fractions upon the flash and burning point constants of ordinary kerosene, we have determined the influence upon them in the case of a kerosene mixed with "low test" gasoline, "high test" gasoline and "petroleum ether."

Both the open and closed cup methods were used for flash point determinations.

The open cup test depends not only upon the skill of the operator but also the condition of the atmosphere and is affected by the slightest current of air. It is a reliable test, however, for such cases where an oil will be heated in open vessels to determine to what degree it can safely be heated without ignition by flame. With such a case the open test is an actual imitation of the real conditions and therefore fully warranted.

The flash point of kerosene should be high enough so that it will insure safety when the kerosene is burned in a lamp. Danger from a petroleum lamp can occur if the flame flashes back into the petroleum reservoir by accident or carelessness and ignites the vapors which had accumulated in the closed basin (Am. Soc. Test. Mat. 10, p. 464, 1910).

The Foster Cup Method is the standard method for determining the point of kerosene prescribed by law in Ohio, which states that kerosene shall not flash below 120° F. by this method. (Allen's Commercial Organic Analysis III, p. 127.)

Method of Using Open Cup Procedure.—For determining the open cup flash and burning points an apparatus similar to the Cleveland Open Cup was used with the addition of a casing to more efficiently prevent drafts of air. A sketch of this apparatus follows (Fig. 3). It consisted of a 40 cc. nickel crucible "A" whose upper surface measured about 4 cm. in diameter. This was placed inside a large 120 cc. nickle crucible "B" which contained sand to a depth of about 2 cm. This sand bath was then supported in the flame guard "C" by means of the asbestos board "D" which had a hole cut in its center to admit "B" as shown. The flame protector was supported on the tripod stand "E." Heat was supplied by the Bunsen burner "F" as shown. The whole apparatus was protected from air current by the casing of thin sheet copper

"G." A thermometer was held suspended in the oil by means of a burette clamp on a ring stand. An ordinary mouth blow pipe connected to the gas cock by rubber tubing was used as a tip for the flame to be passed over the oil.

After thoroughly shaking the oil sample, the small crucible was filled to within ½ cm. of the brim, this required thirty-two cubic centimeters. The thermometer was then lowered by sliding the burrete clamp on the ring stand. The thermometer was held

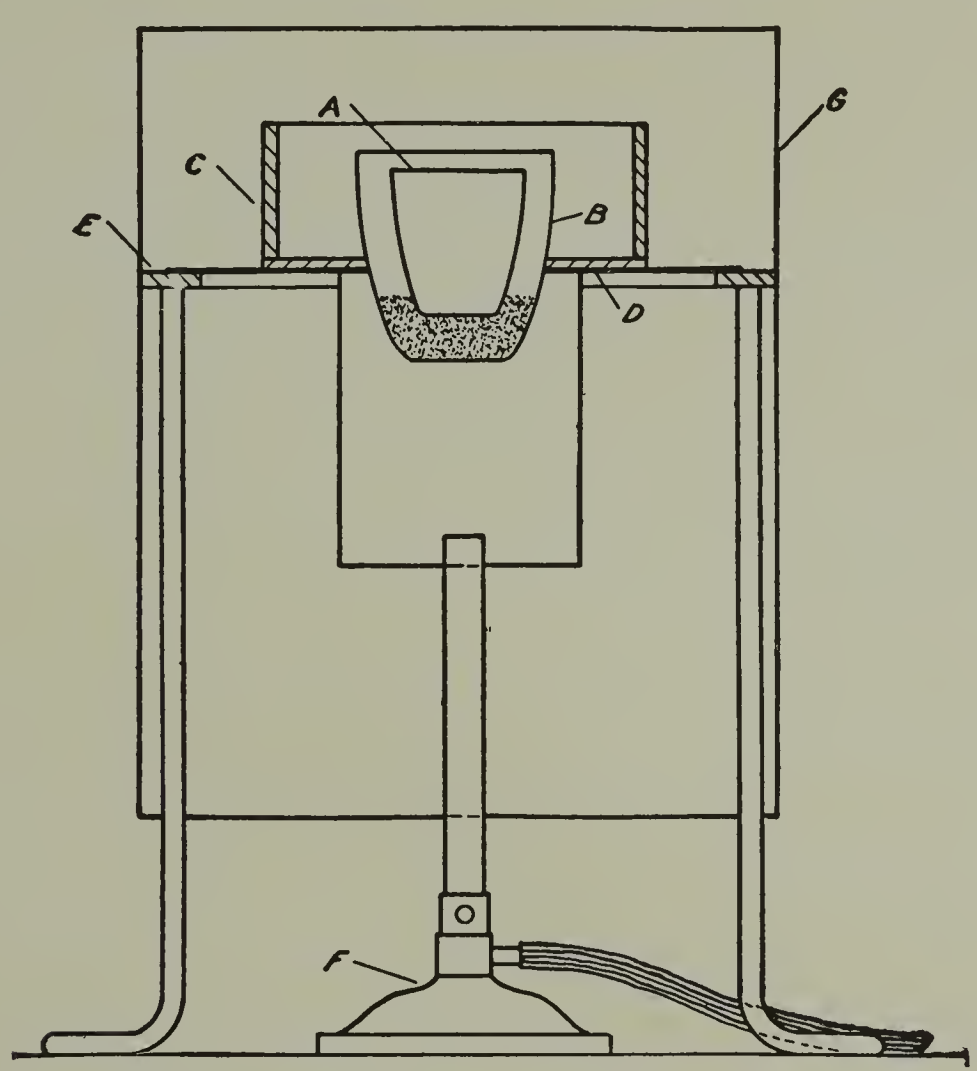

Fig. 3.—Open Cup Oil Tester.

at such a height by the clamp that when the clamp was lowered to the top of the copper shield the bulb was totally immersed in the center of the oil to the same depth each time. Heat was then applied by means of the Bunsen burner, so that the temperature rose at the rate of 5° C. per minute. The test torch was then lighted and the flame made ½ cm. in length. As the flash point was approached, for every degree rise in temperature the flame was passed slowly over the cup horizontally about 1 cm. above the surface of the oil and near the thermometer.

After obtaining the flash point, the test flame was still passed over the oil in a similar manner until the oil permanently ignited. The thermometer was then quickly raised from the oil and the flame in the cup extinguished by excluding the air by means of a solid piece of asbestos board placed over the cup.

All open cup temperatures were read on a 400° Centrigrade thermometer. The calibration of this thermometer was checked up by comparing its two fixed points 0° and 100° C. with a standard thermometer. To fix the zero point, the thermometer was surrounded by melting ice and the reading compared with that of the standard thermometer under the same conditions. The 100° point was then determined by placing the bulb of the thermometer used in the neck of an Erlenmeyer flask containing boiling water so that it was entirely surrounded by steam and the reading on the thermometer was noted, in comparison with that of the standard thermometer under like conditions. The barometer reading was also taken and corrections applied. The uniformity of the bore was checked up by detaching a thread of mercury and measuring its length throughout different portions of the stem between 0° and 300°. Required corrections were applied throughout all of the work.

For each succeeding test the warm sand from the test preceding was emptied from the cup and fresh sand put in so that all tests were made under exactly the same conditions. The cup was then cooled by immersion in cold water and thoroughly dried.

In testing mixtures where the flash point was below room temperature, the sand was omitted from the bath and cracked ice, or ice plus calcium chloride, when necessary, was substituted. Cases where this was required are marked on the table by an asterisk (*).

Method of Using Closed Cup Procedure.—A standard Foster Cup apparatus was used. Its thermometer was checked against U. S. Bureau of Standards Thermometer No. 4576. The method of procedure in determining the flash point by the Foster Cup was as described in Stillman's Engineering Chemistry, pp. 448-449. This was as follows: The thermometer with its mounting was removed from the oil cup. The oil cup containing the flashing taper was removed and the open water bath half filled with water. The flashing taper was then removed from the cup and, after thoroughly shaking the oil in its container, it was carefully poured into the cup at the place of the flashing taper wick holder until it just

reached the gauge mark at the thermometer hole. The cup was then tipped so that the oil flowed away from the gauge, it was then gradually restored to the horizontal position. If the surface again adhered to the mark, it was all right; in case it did not, a little more oil was added. The flashing taper was then adjusted to give a flame "¼ inch" in height. The oil cup was now set in the water bath, the flashing taper returned to its place, the conical thimble inverted around it and the thermometer returned to its place upon

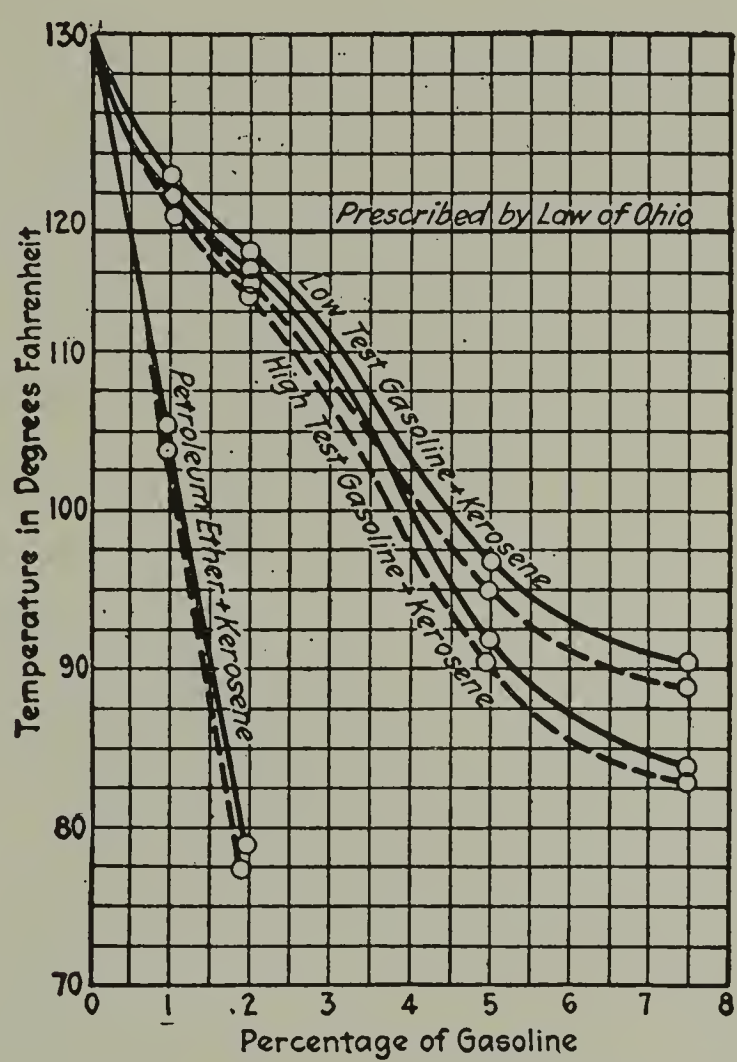

FIG. 4.—Open Cup Flash Point Curves.

the cup, care being taken that the latter was pushed down upon the cup as far as possible. The lamp beneath was half filled with alcohol, lighted, and placed beneath the water bath. The wick was so adjusted that the temperature of the oil was raised at the rate of "2° F." per minute. When the thermometer read 90° the flashing taper was lighted and closely observed. In tests where the flash point was 90° or lower, the flashing taper was placed in the cup before applying heat from below. In several instances as previously mentioned in the open cup method, the mixtures flashed below

room temperature. In these cases cracked ice was placed in the water bath and the test repeated. These cases are shown by an asterisk (*) in the tables.

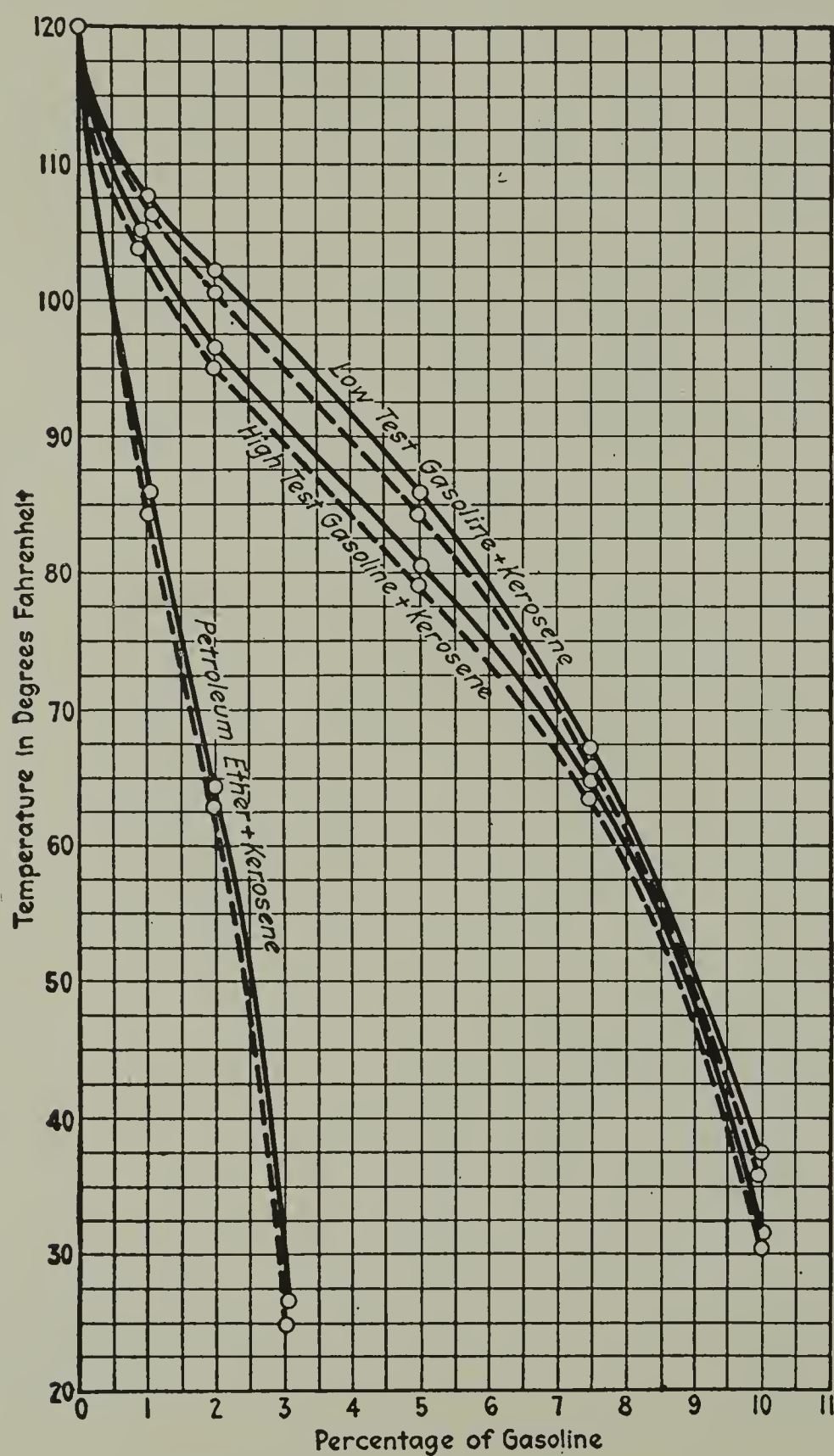

FIG. 5.—Foster Cup Flash Point Curves.

A rather peculiar phenomena took place in the closed cup flash test. When the oil was previously cooled by ice, it flashed some 5 or 6 degrees higher than when not previously cooled. Thus, in

the case of the 7½% mixture of high test gasoline and kerosene, when ice was not used in the bath it flashed at 75° F. (as soon as the pilot was lighted), however, when previously cooled by ice, the mixture had to be heated to 84° F. before flashing, the pilot burning constantly. This may be due to the design of the cup. The flashing taper when in place forms a draft so that when lighted while the oil was below 75° the volatile gases liberated would pass

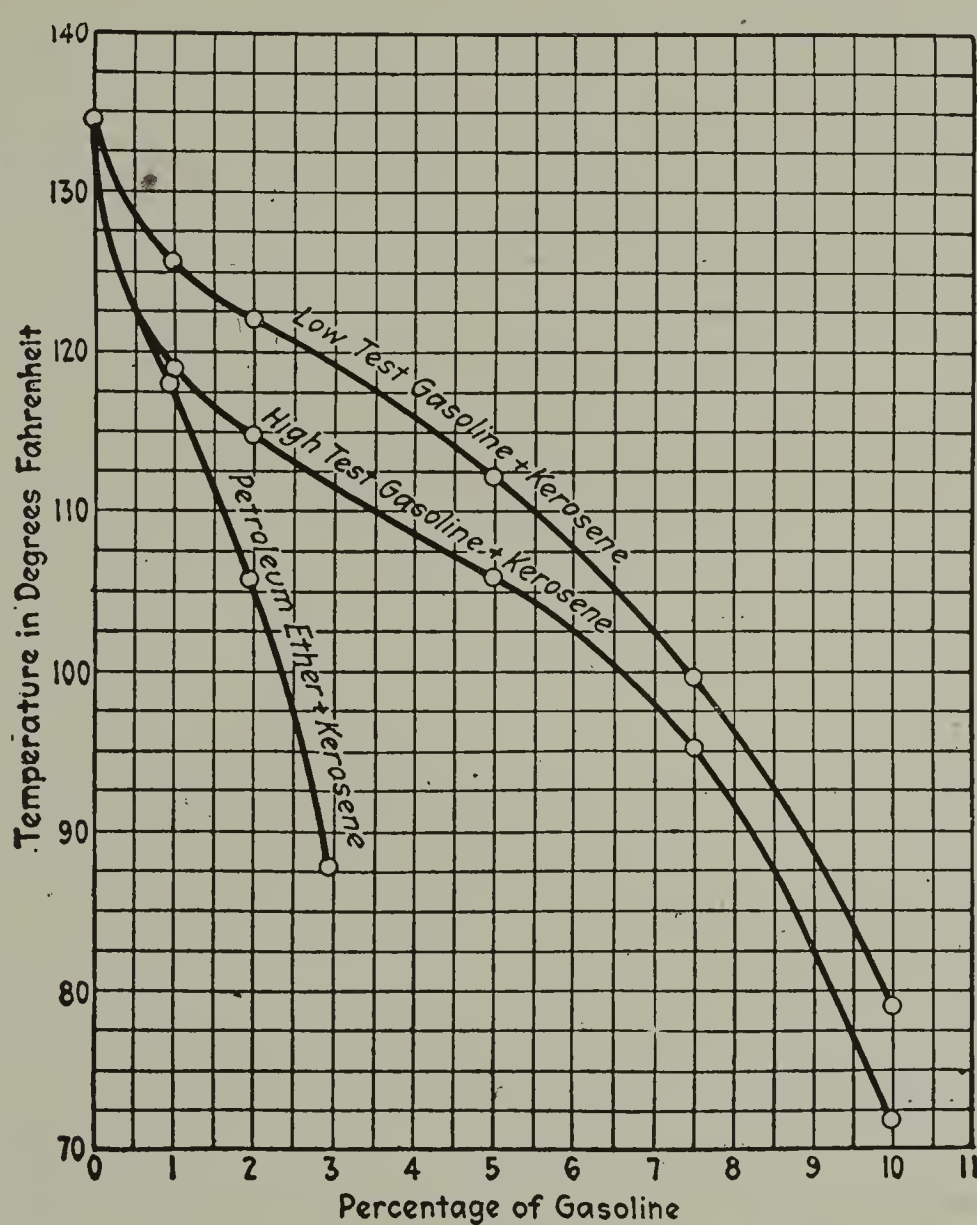

FIG. 6.—Burning Point Curves.

out through the opening and escape, whereas when no light was present the draft was not so great and consequently the concentration of highly volatile vapors in the cup would be greater so that when a flame was admitted at 75° the concentration of the gases was sufficient to extinguish it.

All flash points in both open and closed cup have been corrected for normal barometric pressure, 760 mm., by Table I. (U. S.

Bureau of Mines Technical Paper No. 49). In order to show to what extent the barometric pressure affects the flash point, the solid curves have been drawn which represent the flash points when corrected for barometric pressure and the dotted curves which do not include barometric pressure correction.

No corrections for pressure have been applied to the burning point results as no correction table was available.

The kerosene before being used in these tests was filtered through filter paper to remove all traces of moisture fog.

Discussion of Results.—The tables and accompanying curves (Figs. 4, 5 and 6) shows the results obtained by these tests. Blank spaces in the tables show that the tests were either unable to be carried out because of the low temperature required or the test was considered unsafe.

FLASH AND BURNING POINTS OF "LOW TEST" GASOLINE AND KEROSENE.

Gasoline by volume.....	0%	1%	2%	5%	7.5%	10%
Kerosene by volume.....	100%	99%	98%	95%	92.5%	90%
Open Cup Flash Point, ° F.:						
Without barometric correction.....	118.4	105.8	100.4	84.2	65.3*	35.6*
With barometric correction.....	120.0	107.4	102.0	85.8	67.0*	37.2*
Foster Cup Flash Point, ° F.:						
Without barometric correction.....	128.9	119.3	114.5	95.0	88.6*	....
With barometric correction.....	130.5	120.9	116.1	96.6	90.2*	....
Burning point ° F.....	134.6	125.6	122.0	112.1	99.5*	78.8*

*Shows that freezing mixture was used in bath.

GASOLINE USED—"LOW TEST."

Specific Gravity = 0.738 = 59.7° Bé. at 15.5° C.

KEROSENE USED.

Specific Gravity = 0.815 = 41.8° Bé. at 15.5° C.

FLASH AND BURNING POINTS OF "HIGH TEST" GASOLINE AND KEROSENE

Gasoline by volume.....	0%	1%	2%	5%	7.5%	10%
Kerosene by volume.....	100%	99%	98%	95%	92.5%	90%
Open Cup Flash Point, ° F.:						
Without barometric correction.....	118.4	104.0	95.0	78.8	63.5*	30.2*
With barometric correction.....	120.0	105.3	96.3	80.1	64.8*	31.5*
Foster Cup Flash Point, ° F.:						
Without barometric correction.....	128.9	118.3	114.0	90.5	82.6*	....
With barometric correction.....	130.5	119.6	115.3	91.8	83.9*	.....
Burning point ° F.....	134.6	118.8	114.8	105.8	95.0*	71.6*

*Shows that freezing mixture was used in bath.

GASOLINE USED—"HIGH TEST."

Specific Gravity = 0.703 = 69.15° Bé. at 15.5° C.

KEROSENE USED.

Specific Gravity = 0.815 = 41.8° Bé. at 15.5° C.

FLASH AND BURNING POINTS OF PETROLEUM ETHER AND KEROSENE.

Petroleum ether by volume.....	0%	1%	2%	3%
Kerosene by volume.....	100%	99%	98%	97%
Open Cup Flash Point, ° F.:				
Without barometric correction.....	118.4	84.2	62.6*	24.8*
With barometric correction.....	120.0	85.8	64.2*	26.4*
Foster Cup Flash Point, ° F.:				
Without barometric correction.....	128.9	103.7	77.3*	.....
With barometric correction.....	130.5	105.3	78.9*	.....
Burning point, ° F.....	134.6	118.4	105.8*	87.8*

* Shows that freezing mixture was used in bath.

PETROLEUM ETHER USED.

Specific Gravity = 0.635 = 89.0° Bé. at 15.5° C.

KEROSENE USED.

Specific Gravity = 0.815 = 41.8° Bé. at 15.5° C.

In the open cup method the flash points of the "high test" gasoline-kerosene mixtures were naturally lower than the corresponding mixtures of the "low-test gasoline," being a minimum of 2.1° F. less at 1% and 7.5% gasoline and a maximum of 5.7° F. less at 10% gasoline. The fact that a minimum difference occurred at both 1% and 7½% shows that the open cup flash point of the "low" and "high" test gasoline-kerosene mixtures did not fall at the same rate with increase in percentage of gasoline.

In the case of the closed cup the flash points for mixtures above 2% high and low test gasoline regularly fall at different rates with increase in concentration of gasoline as shown by the curves falling away from one another. This shows that the open cup method does not bear a constant relation to the closed cup method or, graphically speaking, their curves are not the same shape.

The flash point of the petroleum ether-kerosene mixtures decreased regularly with increase in concentration of petroleum ether so that in the case of the open cup method the curve was almost a straight line and in the case of the closed cup method it was a straight line.

The lowering in the flash point of kerosene by adding petroleum ether was remarkable. In the open cup method 2.9% petroleum ether lowered the flash point of the kerosene about 88.5° F. or as much as for 10% high test gasoline. In the case of the closed cup method 1.8% petroleum ether lowered the flash point about 47° or the same as for 7.5% of high test gasoline.

The decrease in the open cup flash points for the gasoline-kerosene mixtures was somewhat over 1.3 times as much as the decrease in the burning point for the same concentration of gasoline. For example, 10% low test gasoline lowered the flash point 82.8° whereas it lowered the burning point but 55.8°. Ten per cent high test gasoline lowered the flash point 88.2°, and the burning point 63.0°.

In the case of the petroleum ether-kerosene mixtures, the flash point was lowered just about twice as much as the burning point, e.g., 3% petroleum ether lowered the flash point 93.6° and the burning point only 46.8°.

The burning point curves are of about the same shape as the open cup point curves, showing that in the case of the high and low test gasoline-kerosene mixtures the burning points did not decrease at the same rate as each other. In making up mixtures,

the order of addition did not affect results, though such a difference is possible for a time at least on a larger scale.

It is evident that the flash and burning points of kerosene are greatly reduced by small admixtures of more volatile petroleum fractions such as gasoline so that grave danger can easily result therefrom.

Distillation Tests of Fractions Used.—In order that the oils used in this work may be identified the specific gravity was determined by the hydrometer method and distillation cuts of the oils obtained.

The distillations were carried out as prescribed in Technical Paper No. 166 of the Bureau of Mines, with the addition of reading the number of cubic centimeters distilled every 5° rise in temperature as recorded by the thermometer as well as readings at every 10 per cent by volume.

The 250 cc. flask connected with the condenser was filled with 100 cc. of the oil measured in a 100 cc. cylinder. The same cylinder was then used as the receiving vessel. In the kerosene and gasoline distillation the flask was covered with an asbestos box; this being omitted in the distillation of the petroleum ether. Heat was applied so that the distillation proceeded at the rate of about 5 cc. per minute; the entire distillation requiring about 25 minutes. The thermometer used in these distillations was the same as that previously described as being used for the open cup flash and burning point determinations. Besides applying the calibration correction, a correction was added for the emergent stem of the thermometer, varying up to 2.5° C. Formula for corrections was obtained from Physico Chemical Tables, Castell Evans, vol. 1, p. 126, J. B. Lippincott Co., Philadelphia, Pa. The condenser trough was filled with cracked ice to insure complete condensation. There were from two to three cubic centimeters of residue left in the flask at the end of each distillation. The results obtained by the distillations are shown in the tables and curves following. Fig. 7 contains all of the oils in order that a comparison may be made between them.

No stem temperature correction was necessary in the case of the distillation of the petroleum ether since the last fraction boiled off at 103° C. as recorded by the thermometer and the emergent stem began at 105° C. in all cases.

The solid curve represents the distillation when stem temperature corrections have been applied. The dotted curves represent the distillation without stem temperature correction.

E. W. Dean in his report on gasoline distillation, Bureau of Mines Technical Paper No. 214, p. 29, plots the dry point on the

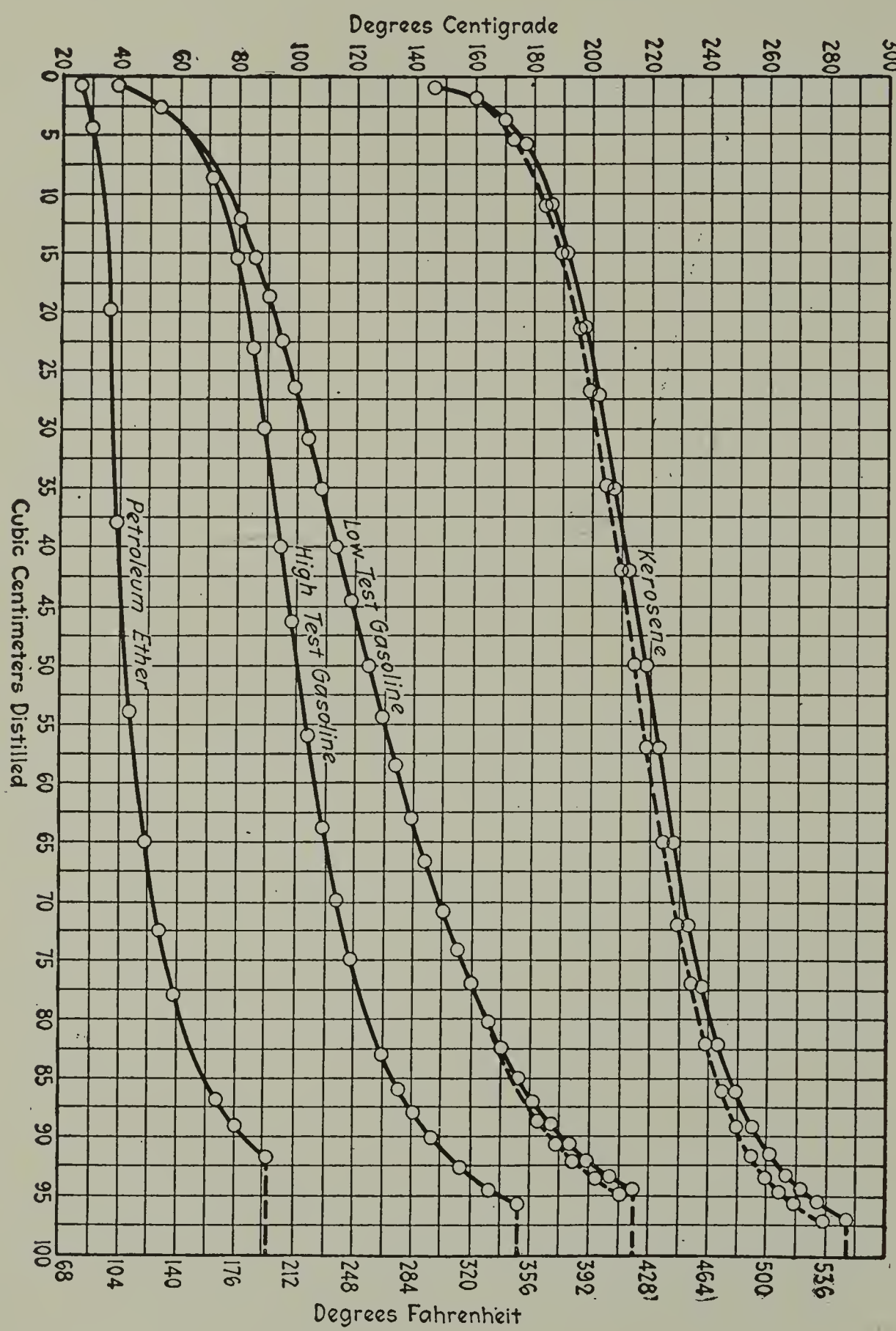

FIG. 7.—Distillation Curves.

100 cc. ordinate. This is not exactly correct since the dry point is always obtained before 100 cc., the initial volume of gasoline have

Temp. ° C.	Temp. ° F.	Kerosene.	Low Test Gasoline.	High Test Gasoline.	Petroleum Ether.
24	75.2	....	....	....	1.0
29	84.2	....	....	....	4.5
34	93.2	....	....	....	20.0
38	100.4	....	1.0 cc.	....	....
39	102.2	....	....	....	38.0
41	105.8	....	....	1.0 cc.	....
44	111.2	....	....	....	54.0
49	120.2	....	1.5	....	65.0
54	129.2	....	2.0	....	72.5
59	138.2	....	3.0	....	78.0
64	147.2	....	5.0	4.0	....
69	156.2	....	9.0	5.5	....
71	159.8	....	....	10.0	....
74	165.2	....	10.5	....	87.0
79	174.2	....	12.5	15.5	89.0
84	183.2	....	15.5	23.0	90.0
89	192.2	....	19.0	30.0	91.0
92	197.6	....	....	....	91.5
94	201.2	....	22.5	40.0	....
99	210.2	....	26.5	46.5	....
104	219.2	....	30.5	56.5	....
109.2	228.6	....	35.0	64.0	....
114.2	237.6	....	40.0	70.0	....
119.3	246.8	....	44.5	75.0	....
124.5	256.1	....	50.0	81.0	....
129.6	265.3	....	54.5	83.0	....
134.7	274.5	....	58.5	86.0	....
139.8	283.7	....	63.0	88.0	....
145.0	293.0	1.0	66.5	90.0	....
149.1	300.4	....	71.0	92.0	....
155.3	311.5	1.4	74.0	93.0	....
160.4	320.7	1.8	77.0	94.0	....
165.6	330.1	2.4	80.0	94.5	....
170.8	339.4	3.3	82.0	95.0	....
175.9	348.7	5.5	85.0	96.0	....
181.2	358.2	8.5	87.0	....	....
186.3	367.3	11.0	89.0	....	....
191.5	376.7	15.0	91.0	....	....
196.7	386.1	21.5	92.0	....	....
201.9	395.4	27.0	92.5	....	....
207.1	404.8	35.0	93.0	....	....
212.4	414.3	42.0	93.5	....	....
217.7	423.7	50.0	95.0	....	....

Temp .° C.	Temp. ° F.	Kerosene.	Low Test Gasoline.	High Test Gasoline.	Petroleum Ether.
222.8	433.2	57.0	....	....	....
228.1	442.5	65.0	....	....	....
233.4	452.1	72.0	....	....	....
238.7	461.7	77.0	....	....	....
244.0	471.2	82.0	....	....	....
249.3	480.7	86.0	....	....	....
254.6	490.3	89.0	....	....	....
260.0	500.0	91.5	....	....	....
265.3	509.5	93.5	....	....	....
270.3	518.5	94.5	....	....	....
275.7	528.2	95.5	....	....	....
281.3	538.3	96.0	....	....	....
286.9	548.4	97.0	....	....	....

DISTILLATION TESTS IN TEN PER CENT. CUTS.

Volume in Percentage.	Petroleum Ether.		High Test Gasoline.		Low Test Gasoline.		Kerosene.	
	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.
10	31.0	87.8	71.0	159.8	73.0	163.4	185.0	365.0
20	34.0	93.2	83.0	181.4	90.0	194.0	195.6	384.1
30	36.5	97.7	89.0	192.2	103.7	218.6	204.2	399.5
40	39.5	103.1	94.0	201.2	114.2	237.6	210.3	410.4
50	43.0	109.4	101.0	213.8	124.4	256.1	217.6	423.6
60	47.0	116.6	106.0	222.8	136.7	278.0	225.1	437.0
70	52.0	125.6	114.2	237.6	149.0	300.2	232.3	450.1
80	61.0	141.8	123.9	255.0	165.6	330.1	241.5	466.6
90	84.0	183.2	145.0	293.0	190.0	374.0	256.9	494.5

been received. Plotting this, results in the curve ending in a sharper bend than it should. To obviate this error, we have plotted the actual dry point on the curve where it is observed and extended a straight horizontal dotted line to the 100 cc. ordinate in order to show where the curve would come had Dean's method of plotting been used. This actually represents approximate loss in distillation.

For convenience, the ordinates are labeled both in Centigrade and Fahrenheit readings.

We are indebted to Mr. Frank C. Vilbrandt, Instructor of Industrial Chemistry in this laboratory, for material assistance in the

search of the literature for data covering the ground of this report and kindred topics.

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July 2, 1919.

SHOULD CHEMISTS BE REGISTERED AND LICENSED?

By EDWARD GUDEMAN.

Read at the Boston Meeting, June 18, 1919

Necessity of the proper recognition of the chemical profession, to me, is not a question open to argument. It is a required CONSTRUCTIVE PROTECTIVE RECONSTRUCTION problem. If it is a question at all, it can only be answered in the affirmative, as there is negative core to this problem. No one denies that something should be done to place the chemical profession where it really belongs and to give to it the standing it has earned and which it should have.*

Individual, generally personal and business, considerations are out of place, as we must take existing conditions and consider where we stand in the eyes of the public. We cannot be critical as to our individual standing to-day as a profession and to those in it, even if not of it; we must grant equality, whether it exists or not, as to scientific standing and ability, and then gradually change the existing conditions for the better. We are in no worse position than were the medical and legal professions before they had to toe the marks of registration and licenses to obtain "legal" status.

We must accept, at least for a reasonable time, as of equal value diplomas, certificates and other credentials, irrespective where, when and by whom issued. Admiration and loyalty to "Our Alma Mater," if we have any, must be forgotten. Chemists who have not had the opportunity of such a "higher" education, cannot and should not be discriminated against, especially as we all can point out many "self-made" chemists, who are the equals, and often the superiors to those holding degrees.

*Gudeman, "Standards of Food and Drug Chemists," J. I. and E. Chem., Aug., 1914, "Aspects of Some Chemical Industries in the United States, To-day," same Journal, February, 1915. "Reconstruction Aspects of Some Chemical Industries in the United States, To-day," same Journal, in print. Read A. I. C. Eng., Chicago Meeting.

The doctor's degree in science or philosophy, judging solely by myself, a self-psycho analysis, does not guraantee anything as to super ability, and at best is only a card showing overtime, perhaps misspent at some educational institute. A foreign doctor's degree does not even mean overtime given to education, and many of us can point out chemists having a foreign Ph.D. degree, who were unable to get an American bachelor's degree.

Registration and license, with the proper requirements and safety guards to obtain them, will give to the chemical profession, some "actual," some "real-official or legal" recognition, and in that way at least place this profession on a parity with other scientific professions, such as those of medicine, law, pharmacy, engineering, dentistry and veterinary sciences. How many will place themselves KNOWINGLY into the hands of doctor or lawyer, who has no license and is not registered to practice the profession? We cannot be married without a license, common-law marriage in some states being the exception; we are not legally born without being registered and even the undertaker must have a license before he can bury or cremate us. I grant that we seldom bother ourselves to make special inquiries on these points, as we take it for granted that the professional men and women, directly or indirectly involved from the day of our birth to the hour of our burial, have a recognized "legal" right to perform the functions of their professions. We feel safe in knowing that if they have not, they are subject to indictment and punishment. In effect licensed, registered, ordained, permitted or admitted to the bar, are similar terms, conferring some fixed rights or privileges. Some may prefer the union card, now by choice, later on by compulsion perhaps, but the fact remains that the union card is a recognition of a specific trade or profession. Remember that to-day many labor unions are numerically not as strong as the chemical profession. Union, federation, association, society or institute are synonomous terms, meaning a grouping of trades or professions, and they all give or intend to give more or less recognition to those that are in them.

Some of us who have felt this necessity of recognition, this absence of legal status, have tried to supply it, by taking "chemical" or other scientific examinations, not with the intention of being appointed to office, simply to be placed on parity with such "qualified" or "recognized" appointees. A similar effect is produced by those connected with educational institutions, using their positions as

badges showing a qualified and recognized scientific standing. I admit making use of both subterfuges, a compulsory requirement to satisfy some clients who want me to "qualify" as an expert.

How often do we find in court proceedings, or at hearings before commissions or committees, that a federal or a state or a municipal chemist qualifies as having passed an examination to obtain the official position he holds, and how often do teachers or ex-teachers qualify as such, the only object therefore being to get the prestige or the recognition that goes with the statement, indicating a standing in the profession, which may give some extra weight to their statements or testimony. To counterbalance the effect produced, compels many experts to qualify in a similar manner, even against their own inclinations. Such qualifications, really references, mean nothing particular as to scientific standing, or as to ability, being play to the grandstand and generally puts the profession as a whole into a false light. Many judges holding this opinion, have little use for chemical qualifications, holding that such qualifications with mass attacks of similar evidence, to convey the impression of a preponderance of evidence, should not prevail. Many judges hold that if there is any scientific merit to a contention, it does not require an army of "qualified" chemical experts to bring it out. If the chemical profession were recognized, membership in the profession would be qualification complete.

If the chemical profession were legally recognized, chemists could be held responsible for what they did and for what they said, and direct breaches in professional conduct could be properly dealt with. Without the least bit of professional responsibility resting on the chemist, consider how often they are called upon to advise on matters effecting the health and welfare of individuals or communities. How often are chemists called upon to advise, perhaps even decide, as to the actual liberty or death of a fellow-being? Such decisions come to many of us as common occurrences, and why should not we be held responsible for our professional actions? Why should we be in a different position from physicians, druggists, engineers, lawyers, or any other professional man or woman, who may have to decide on similar questions?

A physician giving a wrong treatment, can be held for malpractice. Carelessness of a druggist or engineer, makes them subject to criminal indictment. Unprofessional conduct by a lawyer, may close the court room to him, and he can be disbarred from prac-

tice. Ministers not ordained are denied the right to functioning at weddings or funerals.

The right to use the term doctor or druggist or minister is prohibited in many cases, unless one is registered or licensed as such.

Anyone can call him or herself a chemist, act as such in civil or criminal cases, qualifying as a chemical (?) expert and thereby becoming a privileged witness and give an opinion. Being a chemist means nothing specific in the eyes of the law, as our profession is not a recognized one. How often are we asked to define what is a chemist? After having qualified as a chemist (?), we are proof against any indictment and punishment, if our reports or statements or testimony is absolutely false, as long as no proof can be brought showing that we testified falsely with the intention to deceive. Lack of knowledge or experience are not considered, as long as we don't wilfully and knowingly perjure ourselves. All that we have to do to escape responsibility is to give our chemical expert opinion, claim it as our own and stick to whatever statement we have made, correct or otherwise. No doubt many can give better and more appropriate examples than the following:—In a court case Mr. X is accepted as a qualified chemical expert, having qualified himself as a professor in a medical college, that he has a medical degree and many years of practical chemical experience. He then testifies that—A product that has been heated in a furnace for twenty-four hours, is withdrawn hot from the furnace, allowed to stand in a cold room for twenty hours, during which time the temperature of the product, inside and outside of the mass drops about 30 to 40 degrees, is BEING CONTINUOUSLY HEATED, during this whole time outside of furnace, admitting that no chemical reaction takes place, producing heat. Confronted with printed authorities showing the fallacy of his statement, states he is the authority for that opinion, and above any authority that anyone could cite against him.

This expert held no chemical degree, but his opinion stands as part of the court record, notwithstanding that the presiding judge dismissed this witness, without allowing any cross-examination, having the record show that the judge did not believe this conceited chemical expert, and was sorry that the court could take no further action, as the witness had no professional standing, as a chemist, of which he could be deprived. In asking for a new trial, on appeal, these remarks of the presiding judge were quoted to show error and prejudice against this witness. If our profession were

recognized, such a witness might not have been accepted as an expert, and even if he had, this court record could be made the basis for some action leading to his future disqualification, through cancellation of registration or withdrawal of license, or whatever mark he had showing him to belong to the chemical profession, thereby depriving such a person from acting as a member of the chemical profession.

From another case, tried within the last few years in the Superior Court of Illinois. This case has the added interest, that the plaintiff qualified himself or designated himself as a chemist and gave chemical testimony for himself:

Question to the Plaintiff.—"Are you willing that a chemist, to be named by the court, without consultation with either party and whose fees shall be paid by the defendant, should take this sample . . . marked . . . , analyze it chemically, and come here and report what he finds?"

Answer by the Plaintiff.—"I don't know that I am willing that the head of the chemical department of either Northwestern University or of the State University of Illinois, or of Armour Institute of Chicago, any of the three, should take this sample. I want to make further investigation before I leave it to anybody." The University of Chicago and Rush Medical School were later added to the excluded institutions. The Plaintiff played no favorite in barring all local institutions). "I have read all the reports of Congress on the question of using . . . that were before the Pure Food Commission at Washington. That threw such SUSPICION at ALL chemists that I wouldn't trust any of them until I looked them up pretty well. I cannot name any chemist in the United States to whom I am willing this sample should be submitted. My objection is to chemists in general all over the United States, following pretty closely . . . decision on that. If I could find a chemist in the United States who would be available during this trial, who could satisfy me I can get a GOOD HONEST analysis, I would willingly submit it to him. I haven't any such chemist in mind. So far as I know at this time there is no person whom you could name or anyone could name who would be satisfactory. There is not any chemist in the United States so far as I know, who is available or within reasonable distance of Chicago, so that he could make the

report suggested while the case is on trial, to whom I am willing to submit this for analysis."

I do not believe that the plaintiff tried to confine his selection to Chicago and its suburbs, that mentally he included Eastern and Western institutions as well, as he states his inability to find a good and honest chemist anywhere in the United States. This case was on trial for some weeks. The analysis called for, would not have taken much time, a few hours perhaps, was qualitative, requiring no special reagents nor complicated apparatus, and no extra amount of chemical knowledge. Within forty-eight hours chemists could have been brought to Chicago, from St. Paul, New Orleans, Washington, New York or even Boston and the analysis could have been made in any laboratory.

Whether the chemist plaintiff's opinion as to chemists in the United States was partly or fully justified, you can judge from the abstract of his attorney's address to the jury, viz:

"Now suppose by the way of illustration, that you had some trouble that required you to consult a lawyer and you go to him and lay your case down before him, your papers and your statement of your contention, and he accepted the evidence that you gave him as to what you claimed to be right, when at the same time he knew he was the employee of the party against whom you were complaining. Suppose that was me and I accepted the retainer to represent you if there was trouble, just as . . . represented . . . in this court.

"I get your evidence and find the inside of your case exactly, what your claims were and then afterwards when the time comes for action, you find that I am in the employ of the party complained of and make use of the very evidence I get from you for the purpose of giving advice. A lawyer who would do that would be DISBARRED and BRANDED and DRIVEN from the PROFESSION. I would not hang a yellow dog upon evidence of a man of that kind."

Suppose you had been on the jury, and the attorney's statement, referring to some of the chemical experts, was true and substantiated by their own statements in the record, what would your verdict be? I wish to add that none of these experts refererd to were members of our Institute. How does such unprofessional conduct reflect on chemists and on the profession? What can we do to stop this and prevent a recurrence? Absolutely nothing.

Only a few days ago, in the Chicago *Herald Examiner* of May

22d, 1919, there appeared the following editorial headed "THE NATIONAL RESEARCH COUNCIL:"

"Dean Angell of the University of Chicago, recently asked to be president of the University of Michigan, has accepted the position of president of the National Research Council at Washington.

"The purpose of the council is to promote research in *mathematical, physical and biological sciences*, and in the application of these sciences to *engineering, agriculture, medicine and other useful arts*, with the object of increasing knowledge, strengthening the national defense and contributing in other ways to the public welfare.

"While the war was going on the council had direct charge of all experiments for war purposes. Under its direction discoveries were made which were worth armies. Its workers increased the range of five-inch guns by seven miles, and their accuracy eight times; introduced wireless telephoning for airplanes; *developed the manufacture of gas to a point which, if the war had continued, would have staggered the world; revolutionized the American dye industry*, and in a hundred other ways made American science the wonder of other nations.

"Now in peace it means to continue its organization, and if possible its successes."

You will note that mathematical, physical and biological sciences are directly mentioned. Reference is made to the manufacture of war gases, and the revolutionizing of the American Dye Industry is recognized. I do not know whether Mr. Arthur Brisbane wrote this editorial, but whosoever did, does not seem to know that such a thing as chemical science exists, and that there is a tribe of professionals who designate themselves, without any legal authority, as chemists. We cannot wholly blame the laymen for the non-recognition of our profession. What is granted to us after completing a college or university course in chemistry? A degree of Bachelor in Science or Philosophy, with or without mentioning that chemistry was our major study. Judging by my own diploma, certifying to the granting of the degree of Doctor of Philosophy, no one can tell whether it was granted because I wrote the great American novel or for finding the origin of the Sanscrit alphabet or whether it was accidentally due to some extra work in chemistry.

We grant specific degrees to engineers, even to sanitary and chemical engineers. When one graduates in law, medicine, pharmacy, dentistry, theology or veterinary science, the degree mentions them

and it is so stated on the diploma or certificate issued. Why should not the chemical profession have its own degree, instead of being buried under a "science" or "philosophical" tombstone. We are no more bachelors or doctors of philosophy than we are of law, medicine or theology. If our educational institutions do not specifically recognize us by our own name, we certainly cannot expect the recognition from the public, the laymen. Does not the chemical profession deserve this institutional recognition and this protection? You can substitute any other designation you prefer for "registration and license," some other name may sound sweeter, but we must decide on a something, some card, tag, insignia or label, which identifies the standing of our profession, which carries rights and privileges and responsibility, without which no chemist should be allowed to practice, and which rights and privileges can be annulled and of which we can be deprived, if we do not live up to at least a minimum standard of professional chemical ethics.

Membership in chemical societies, with or without codes of ethics, are not sufficient, and carry little weight, attach no responsibility to a professional chemical standing, and do not indicate scientific ability nor integrity. I say this with a full recognition that our Institute requires scientific standing to enter it, and also has a splendid code of ethics, limited to our membership, seldom made use of, perhaps not even enforcible. You know well that many of our fellow chemists sneer both at our entrance requirements and at our code and that numerically we are not strong enough to have them given much consideration by outsiders. We can initiate a move to bring about a proper recognition of the chemical profession. Perhaps we are not the proper force to do this, for although many of our members are chemists, still our Institute is composed of "CHEMICAL" engineers, our chemical part being adjective. Membership in many "scientific" societies used as qualification as to chemical or other expert standing is often a farce. Some time ago, a very well-known American chemical expert, qualified as a member in some ten to twelve scientific societies, omitting to mention our Institute, but made up for this by mentioning the National Geographical Society. On cross-examination it came to light that only one of these societies required a scientific standing, and of this one he was an honorary member. We all know that the only requirement to join most chemical societies in this country and abroad, is the inclination and ability to pay the annual dues.

Within the last few months many of us have been given proof of the urgent need, have heard the call, and see the handwriting on the wall, for some real recognition of the chemical profession. Are we going to heed this, or will we await the Federation of Labor to usurp our duty?

Many of us have received applications from chemists, who for a time were in employment of our government. Not alone in these applications, but in notices and in advertisements in our chemical and trade journals, do we find stress is laid on the fact that the applicant or the one returning to civic duties has been in government chemical service. It is a sort of official recognition that they have the right to call themselves chemists, showing that they belonged to a specific profession.

A league of those who have this right of having had the honor to wear the chemical war insignia, will bring about for them a proper recognition, good at least for one generation, and will make all other chemists, outside of this select circle, do something to also get some kind of recognition.

If the chemical profession is on parity with other scientific professions, it should have some official and legal standing, and it makes no material difference how this is brought about and how it is certified, to whether by license or registration or any other act. If our profession carries responsibilities as great as those of other scientific professions, and no one denies this, we should have similar rights and privileges, including some chemical court of honor, where these rights and privileges can be curtailed, suspended or annulled, if necessary. The fact that lawyers and physicians are registered, licensed or admitted to practice has not lowered the dignity of these professions, in fact has perhaps added dignity to their professions, and the same will apply to chemists.

We are still to-day a known public factor, gradually again fading away, as does the chemical War Service Department, which is to be absorbed and its identity lost in the War Department. It will not be difficult to give ourselves now a "legal status" obtaining state recognition, perhaps with the appendages of registration and license, before being allowed to call ourslves chemists and practice as such.

State acts recognizing the chemical profession, through proper examination or otherwise would create no hardship on any of us, and would be of direct benefit to most chemists and all chemical industries, as it would prohibit every Tom, Dick and Harry, Mary and Jane

from claiming to be of our profession. To-day we have less responsibility thrust upon us than a new-born baby, and we get less hearing and attention than a baby, whose presence and existence is recognized, even away from its own home, if only through its howling influence, often in evidence during the dark hours of the night. The chemical profession has its dark hours both day and night, again being satisfied to peacefully slumber in the darkness of non-recognition. We should wake up and set up a mighty howl, and to pacify us, we will be fed on recognition. What this specific diet is to be called, can be decided upon later, as long as we don't begin to Hooverize it.

Col. F. M. Dorsey is in accord with some action, as he wrote to me on May 5th, 1919, as follows:

"I do certainly agree with you that the chemical profession should be legally recognized, but am sure that I do not know, at the present time, how this should be done. I am a member of a committee for the American Society of Ohio, which has for its function the following of legislation on this point. There are so many angles to the problem that I have not at this time reached a conclusion as to how it can best be solved."

As Col. Dorsey says it is a great problem worthy of grave consideration. I doubt whether anyone to-day can solve it to the satisfaction of every chemist, but I believe we can start in on it, act together with representatives of other chemical societies, to get a proper recognition, whatever it may be or may be called, to get legal status, and it certainly should not be a difficult task to get at least degrees in chemistry from our educational institutions, which would be some recognition and some protection.

If what we call chemistry is only a handmaid to other scientific professions, then nothing further need be done, and we can continue to sit in the back row. But if CHEMISTRY is a REAL PROFESSION, able to bear its own burdens and has responsibilities, then it is about time for the profession to get the RECOGNITION and the LEGAL STANDING due it. A former president of the American Chemical Society some years ago said:

"We have in this country the capital, the enterprise and the chemistry for great industrial achievements, that we cannot thus far point to them is due to the fact that with us chemistry is too often left like Cinderella sitting besides the ashes of the laboratory furnace, while her two haughty sisters drive to the industrial ball." To-day

I believe that Dr. Little will not object to my finishing his chemical fairy story, by saying that Cinderella Chemistry has been to the ball and made a world's sensation. The Prince of Opportunity has found her and has married her. He is now leading her home to give her the position due her in scientific society. Two homes are open to her, one containing the registered and licensed fellow scientists, and the other offering the recognition and protection of the labor unions. You can choose for her, which will you take?

CHEMICAL ENGINEERS AND STATE LAWS FOR LICENSING ENGINEERS AND CHEMISTS.

By JAMES R. WITHROW

Read at the Boston Meeting, June 20, 1919

CHEMICAL engineers and corporations employing them should watch their respective legislatures and local societies of engineers to guide into proper and desired channels the flood of legislation concerned with the growing demand for the licensing of professional engineers.

Failure upon the part of chemical engineers to assist in this task will result in absence of representation of chemical engineers upon the various State boards.

PROFESSIONAL LICENSING IN GENERAL.

For years there has been agitation among other professions for licensing laws such as provided for and "enjoyed" by the medical profession. It is claimed that the public would thereby be given a sort of basic, preliminary or partial protection against gross inefficiency and to this extent against fraud. Individually, the profession itself would be enabled to render more direct and effective public service in that it could be called upon collectively for such service. The profession would, of course, profit to the extent that it received public standing and recognition. No one claims that the medical practitioner is made more capable or honest by his license, but it must be admitted that the less capable have been lopped off, the plane of the *lower* level has been elevated and a pride of profession created which assists in the elimination of the charlatan from within and clearly brands those without the pale.

This agitation among chemists has cropped out in various forms for a dozen years or more. No time will be spent upon this phase of the subject. Others who, perhaps with reason, feel the need

more keenly will do the subject the justice it may merit. This paper will confine itself to the case of the chemical engineer solely. Those interested in the case of the chemist will find some phases of the matter discussed by Rollin G. Meyers in "A Plea for a Chemists' Protective Association" (Jour. Ind. Eng. Chem., Vol. 7, 795. 1915). Notes on "Chemists' Protective Association (Reply to previous article), Jour. Ind. Eng. Chem., Vol. 7, 1917, p. 1000, by Wm. C. Moore. (Answer to previous article by Moore) Jour. Ind. and Eng. Chem., Vol. 8, 1916, p. 383, by R. G. Meyers. The omnibus committee in its report to the Council of the American Chemical Society (Jour. Ind. Eng. Chem., 11, 413, 1919) takes up a proposal to form an organization among chemists like the Bar Associations.

The gist of discussion of the subject of licensing, by engineers who favor it, would appear to be that "the subject must be considered in regard to its effect on the public, on the engineering profession and on the individual member of the profession. It may be viewed in a selfish way, in a public spirited way or in a professional way."

It would seem that the tendency of licensing would be to protect the public just as it must be conceded is the case with licensing physicians and lawyers. It must also be evident that dangers and losses in which the public is interested may arise from incompetent engineering. The proper design of building machinery, bridges, railways, water-works, is a public concern just as medicine or surgery. The public or private purse of the employer of engineering service is affected by lack of skill quite as much in the case of engineers as of attorneys. Incompetent handling of public or private funds on engineering work is known to probably any engineer.

The profession of engineering should be improved in standards of practice by such legislation for the reason that it would become increasingly difficult for unprepared men to enter the profession.

The improvement in the practice of medicine and law by this means is well known. The engineering profession, like that of law and medicine, would by this means be unified and develop a greater feeling of comradeship and community interest, and this need is as great as it was for medicine and law.

Many States have passed such laws and they are coming in still others. The engineer in a State without such laws is restricted in

his practice thereby. The engineer should anticipate such legislative action in his State and guide or direct it into proper form.

From a selfish point of view the competent engineer has little to gain, except such as comes from the general advantage to the standing of his profession. The main argument is the advantage to the public.

The whole idea of licensing is opposed to the old school of engineering thought. The old engineer feels he must be a free lance, at liberty to do good, as is his constant aim, anywhere or any way he finds to do it. The idea of licensing is repugnant to him as a lowering of ideals. Loss of prestige might also result, he feels. It is said that incompetent men will gain standing by being licensed. He is worried about interference with small construction such as ditches, houses, etc., although in many laws these are exempted, specifically as they would obviously be in the broad interpretation of any law, especially when professional engineering is defined as such work as requires experience, design and calculation.

It is believed by engineers to be doubtful whether there is any other means whereby engineering will so easily secure recognition as a profession by the public or legislatively or whereby the various branches of engineering and architecture will be so readily unified and brought to a sense of their mutual interest and responsibility, as by licensing.

The work of the engineer is as intimately related to the safety and welfare of the public as that of the attorney, physician, pharmacist, public accountant and others whose practice is limited by law to those who are competent. Permission to design and construct chemical equipment, for instance, by incompetent men practicing as engineers, is to court accident, danger and financial loss. At present, inexperienced or improperly prepared men may render the entire profession subject to suspicion and criticism on account of the methods and results of such a situation.

Among engineers the matter is of long standing and acute. But one phase of it need be emphasized, and that by a concrete case. In Ohio, as perhaps a typical one, the county engineer is a constitutional elective officer. There is no legal provision to prevent a barber being elected to the highest public engineering responsibility in any county of the State. So that the laboratory artist of the morning develops into the engineer of the afternoon after every noon-day meal. It would be no odd thing in this State to see the

sign "Shaving in the morning and evening, surveying in the afternoon," or "Horses shod mornings, county bridges in the afteroon."

A man once wrote the State University stating he was elected county surveyor and, wishing to learn something of engineering, asked if there were any books on the subject.

In one county a blacksmith so elected placed on his sign indicating his trade of blacksmithing the statement, "Surveying done on Thursdays." Jewelers and school teachers have held this position in Ohio.

Meeting the Evil.

This evil must be met by two methods: (1) legislation, (2) education. It would hardly be disputed that legislative requirements for responsible professional officers should stipulate professional experience in the candidate. Everyone agrees that this will require education of the public and still more difficult perhaps, education of legislators in the face of political pressure.

It seems practically impossible to get a legislature to make the requirements of a professional office higher than in the profession itself. Where there are no standards or requirements recognized in the profession, the legislature stalls absolutely. For these reasons and the general good of the public in its private engineering work as well as public work, engineers have been actively interested for some time in licensing.

The Proposed Draft of a Licensing Bill for Ohio.

In Ohio the matter has long been agitated by the civil engineers. They have come closest to the evil in public work because of the State land surveying, bridge and road building elective offices. For eight years much study has been given to proposed legislative remedies. The present bill has been carefully studied and compared with the law or bills proposed in other States and with the State medical registration law.

The matter of legislative remedy came up for debate before the Columbus Engineers' Club last winter. In the debate the mining, electrical and mechanical engineers objected on the one hand to a blanket bill covering engineering as a profession which

call all by the ancient term "civil" engineers as distinguished from "military" engineers. They objected on the other hand to a bill which covered true civil engineering solely, for it would prevent a mining engineer from doing above ground surveying, or installing surface engineering works for which he was qualified and compel his corporation to maintain a civil engineer for this work. It was finally concluded that all branches of true engineering, even chemical engineering, must be included in any effective law which is not to do unnecessary harm. The chemical engineer, when competent, should be permitted to survey, lay out and erect his own plant extensions, as well as design and erect his own engineering equipment and even power plant when necessary, without the need of employing other special engineers for this service.

As a result of this discussion, your speaker was appointed representative of the Columbus Engineers' Club at a meeting of the Association of Ohio Technical Societies and by this organization was appointed on its committee to represent Chemical Engineering in an effort to meet the objections raised and redraft the proposed bill. The architectural society requested to be covered and protected in the bill and were ably represented on the joint committee. The result of this labor is the subjoined bill.

The Ohio bill has been criticised for failure to include chemists. The speaker is probably responsible for the omission of chemists from the bill. It never occurred to him to include them. Effort was merely made to protect chemical engineers and not have them omitted as is the usual custom by other engineers. Chemists are not "necessarily included" in the professional work covered by the bill, and except they wish it there is no reason for their inclusion. They rarely have to do with construction and then they should qualify as engineers or they are a menace to others.

The original Ohio Bill as prepared by the Committee of the Ohio Engineering Society, provided only for civil and mining engineers and surveyors. This draft was submitted to the Association of Ohio Technical Societies where, upon the suggestion of representatives of other branches of engineering and architecture, its scope was enlarged. This omnibus character was due to the difficulty of providing for any one branch without handicapping the members of other branches.

It was the consensus of opinion among engineers that there was greater danger due to omission than to inclusion of any group

of engineers because of the overlapping of various engineering branches in modern engineering practice.

It was evidently impossible to cover or protect any branch completely without interfering in some way with other branches. The delegates present at the meeting of the Association of Ohio Technical Societies were unanimously in favor of including all branches and therefore the Ohio bill was extended in scope to do this and the present bill was prepared by a representative committee of this Association.

To give an idea of the way engineers look at this bill the following is quoted from the statement of the Committee on Publicity of the Association of Ohio Technical Societies:

"This bill is drawn primarily in the interest of the public because:

"1. The State considers it important that lawyers, physicians, surgeons, pharmacists and public accountants shall be registered and their practice regulated; it is just as important that the public shall be protected by requiring professional engineers and architects, and surveyors to be registered and their practice regulated, for they practice in a wide field of activities that directly affect the health, life, safety and property of every individual in the State.

"2. Every mistake made by an incompetent engineer or architect, and every fraud perpetrated by an impostor, results in damage or loss to the public, and confidence in the engineering and architectural profession is thereby weakened.

"3. Such legislation prevents the faker and crook from imposing upon the public in the guise of an engineer or architect.

"4. It serves to increase the engineer's and architect's sense of responsibility to each other and to the public.

"From the Viewpoint of the Engineer and Architect.

"1. Such regulations serve to secure recognition of the professions of engineering and architecture both from the public and the legislature.

"2. It serves to unify the professions and to establish higher moral and professional standards among them.

"Anticipating questions in regard to some provisions of the bill, the committee submits the following statements:

"1. All classes of engineers and architects are included because of an apparent demand from most of them for such protection. Various branches of these professions so overlap that if any branch is left out its members will find themselves seriously hampered in their business, and for the same reason, classification is impossible and the bill is necessarily made omnibus in character.

"2. Responsible assistants are included because they ought to be. The law would be a farce if only the chief engineer of a city or large corporation need be registered, while his many assistants in responsible charge of work were not.

"3. The engineer in present practice is given a certificate because it is not permissible to legislate a man out of his means of livelihood, regardless of his competency."

Features of special interest to us as chemical engineers in the Ohio bill have been printed in italics. If read continuously, the italics give a good statement of the chemical engineering influences of the bill. (The italics are not in the bill itself.)

A BILL.

For the better protection of life and property by the regulation of the practice of professional Engineering and architecture in Ohio.

Be it enacted by the General Assembly of the State of Ohio:

SECTION 1. That within six months after the passage of this act, *the Governor,* by and with the consent of the Senate, *shall appoint a State Board of registration for professional engineers and architects* (hereinafter called the Board), consisting of nine members, not more than five of whom shall be of the same political party, three to serve for one year, three for two years and three for three years and the successors of each for a term of three yeas. The *membership of the Board shall include at least one representative of* each of the following branches: civil, mining,

mechanical, electrical and *chemical engineering* and architecture. If the Senate is not in session, the Governor shall appoint such Board and report such appointments to the next session of the Senate for confirmation. *No person* shall be *eligible for appointment as a member of the Board unless he* is, and has been for at least five years, a citizen of Ohio and *has been continuously engaged for at least ten years in the active practice of professional engineering* or architecture *or in teaching such professions, or some branch thereof, in a reputable college or university. Not more than three persons engaged in such teaching shall act as members of the Board at the same time.* Any vacancy in the Board shall be filled by appointment by the Governor.

Sec. 2. The Board shall organize by electing a president and vice-president who shall be members of the Board, and a secretary who may or may not be a member, but who shall conform to the qualifications for such membership. The officers of the Board shall serve for the term of one year.

Sec. 3. The secretary shall receive a salary to be fixed by the Board, and his necessary expenses in performing his official duties. He shall give bond in such sum as may be fixed by the Board, with sureties approved by the Board, for the faithful discharge of his duties. The secretary may employ such clerks and assistants as may be necessary to carry out the provisions of this act, subject to the approval of the Board, who shall fix the salaries and compensation of such clerks and assistants.

Sec. 4. The members of the Board, except a member serving as secretary, shall not receive compensation, but their necessary expenses, while engaged in the discharge of their duties, shall be paid, but no money shall be paid or authorized to be paid either for salaries, expenses, or other purpose in excess of the fund established under the provisions of this act.

Sec. 5. The Board shall have a common seal, and shall formulate rules to govern its action. The Board shall have power to compel the presence of witnesses and the president and secretary of the Board shall have power to administer oaths. The Board shall meet in Columbus on the last Wednesday of June in each

year and at such other times as the Board may appoint. Seven members shall constitute a quorum.

SEC. 6. From and after one year after the passage of this act, *it shall be unlawful for any person to practice professional engineering* or architecture, *as defined in this act,* or to hold public office or employment involving the practice of such professions, or to set or disturb boundary monuments *in Ohio unless such person shall have first obtained a certificate entitling him to practice professional engineering* or architecture from the Board. Such certificate shall state whether the holder thereof is registered as a professional engineer or architect. The holder of such a certificate shall be known as a registered professional engineer or architect, or, if a certificate entitling the holder to practice surveying only be granted, as hereinafter provided, the holder of such certificate shall be known as a registered surveyor. *No person residing in Ohio shall qualify as a witness for the purpose of testifying as an engineering* or architectural *expert in regard to subjects of an engineering* or architectural *nature in any Court of the State of Ohio unless he be a registered professional engineer* or architect, or, if such testimony be in regard to the surveying or platting of land, boundary lines, mines, or of a similar nature, a registered surveyor may so qualify. No map or plat of any land or mine shall be accepted for record in the State of Ohio unless certified by a registered professional engineer or a registered surveyor. *Provided, however, that this act shall not apply* to officers holding office or officers elect, at the time of the passage of this act, during the term for which they have been elected, nor *to engineers* or architects *in the employ of the United States Government,* but *such engineers* or architects *shall not do any engineering* or architectural *work in Ohio except that pertaining to their official positions unless they shall have complied with the provisions of this act.*

SEC. 7. *Professional engineering* and architecture *within the meaning of this act embrace and include all branches of the professions of engineering* and architecture *other than military engineering. Any person who designs or makes drawings for any* building, bridge, railroad, harbor, canal, dock, dam, waterway, street, highway, sewer, sewage disposal plant, water works, water supply, ditch, drainage system, mine, tunnel, dry dock, ship, barge,

dredge, crane, or other floating property, steam engine, turbine, internal combustion engine, or other mechanical structure, electrical machinery and apparatus, works for the development, generation, transmission, or application of power, *apparatus or structure for carrying out* mining and *chemical operations,* refrigerating or heating apparatus or structures, *or other works of similar nature which require for their design experience and technical knowledge, or who makes estimates or specifications therefor, or who directs the construction of such work as engineer* or architect *or who acts as a consulting engineer* or architect, or who surveys or makes maps or plats of any county, township, city, village or of any land, road, lot, subdivision or addition or of any mine, tunnel, stream, or body of water, *or who does any work ordinary known as* civil, mining, mechanical, electrical, *chemical,* metallurgical, ceramic, refrigeration, heating, automotive, valuation, municipal, highway, railroad, structural, hydraulic, sanitary, irrigation or drainage *engineering,* architecture or marine architecture, landscape engineering or architecture, or surveying, *except on his own property, for his own personal use and without receiving money therefor, or who offers or agrees to do any of the above things or maintains a place of business for the carrying on of any of the branches of the engineering* or architectural *professions, shall be regarded as practicing professional engineering* or architecture *within the meaning of this act. Any person doing any of the things specified in this section as resident engineer,* department engineer, division engineer, assistant engineer, clerk of works, *or other similar title, with authority to exercise discretion, assume responsibility, devise methods, or to perform duties ordinarily delegated to such position, shall be regarded as practicing professional engineering* or architecture *within the meaning of this act, even though he be employed by or under the direction of a registered professional engineer* or architect.

Sec. 8. *Nothing in this act shall be construed to prevent the employment of assistants of grades below those named in Section 7 of this act on any engineering,* architectural, or surveying *work, which assistants shall not be required to hold a certificate, provided they are under, and report directly to a registered professional engineer* or architect or a registered surveyor, *who assumes all responsibility for their work. Any engineer* or architect *not*

residing in Ohio may be called in consultation by any registered engineer or architect *in Ohio and shall not be required to hold a certificate to act as such consultant. Any engineer* or architect *not residing in Ohio may be called as a witness to testify upon questions in regard to which he is especially qualified and shall not be required to hold a certificate to act as such witness.*

SEC. 9. *The Board shall issue a certificate entitling the holder to practice professional engineering* or architecture *to any applicant holding lawfully a diploma showing completion of a course in any branch of engineering* or architecture specified in Section 7 of this act, except surveying, *in any college or university whose curriculum is approved by the Board, together with satisfactory evidence that he has had at least two years' practical experience under one or more competent professional engineers* or architects; *or to any member in good standing in the* American Society of Civil Engineers, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, the *American Institute of Chemical Engineers,* the American Institute of Architects, *or other national engineering organization having similar requirements for membership; or to any applicant who within one year after the passage of this act submits to the Board satisfactory evidence that he has for five consecutive years prior to the passage of this act been engaged in the active practice of such profession,* except as qualified by Section 10 of this act, the Board having, however, power to extend such period of one year at their discretion; *or to any applicant who successfully passes an examination before the Board to determine his fitness for such practice;* the provision of this section are subject to the authority of the Board to reject an applicant for cause as provided in Section 12 of this act.

SEC. 10. The Board may grant a certificate entitling the holder to practice land or mine surveying to any person, otherwise eligible under the provisions of Section 9 of this act, whose practice has been limited to such branch, or who, upon examination, satisfies the Board of his fitness to practice the same; but the holder of such certificate shall not be entitled to practice branches of professional engineering or architecture other than the surveying and platting of land or mines.

SEC. 11. *The Board may issue a certificate without examination to any professional engineer,* architect or surveyor *not residing in Ohio, who possesses and presents a certificate from another State, territory, or the District of Columbia, or satisfactory evidence of the possession of such a certificate, provided the laws of such State, territory or district, require of professional engineers,* architects, or surveyors *practicing therein, qualifications equal to those required of such engineers,* architects or surveyors *in Ohio, and provided equal rights are accorded by such State, territory or district to registered professional engineers* or architects or registered surveyors *of Ohio.* The fee to be charged such non-resident professional engineer, architect or surveyor shall be the same as the fee charged by that State, territory or district for a like certificate to a resident of Ohio, but if such State, territory or district has fixed no specific fee for such certificate, the charge shall be $10.

SEC. 12. *The Board may reject an applicant guilty of felony, misdemeanor, misrepresentation, perjury, or fraudulent methods of practice or may, after proper hearing, revoke a certificate for the same cause.* At least one month's notice shall be given to the party at interest before such hearing is given, and he shall have the right to be present with or without counsel. An appeal may be taken from the action of the Board in refusing to grant or revoking a certificate for such cause, to the Governor and Attorney-General, whose decision shall be final.

SEC. 13. An affirmative vote of not less than six members of the Board shall be required to authorize the issue or revocation of a certificate.

SEC. 14. The Board shall keep a record of all its proceedings and a register of all applicants for certificates, giving the name, age, place of residence, educational and other qualifications, whether or not an examination was required, and whether the application was rejected or a certificate granted. The books and register of the Board shall be prima facie evidence of all matters recorded therein. *A schedule showing the names and places of business of all registered professional engineers,* architects and surveyors *shall be filed and maintained by the secretary of the Board in the office*

of the Auditor of State, who shall keep such schedule open to public inspection. The secretary shall furnish certified copies of any certificate on receipt of the fee hereinafter prescribed for such copies, and such certified copies shall be accepted in any Court of Ohio as prima facie evidence of the statements contained therein.

SEC. 15. The fee for consideration of an application for a certificate without examination shall be $10 and for the examination of an applicant the fee shall be $25, and for certified copies of certificate the fee shall be $1 for each copy. In no case shall the fee be returned in event of refusal to grant a certificate, but any unsuccessful candidate may be examined at any one subsequent session within one year without further charge. All fees shall be paid in advance to the secretary of the Board, and by him covered into the State Treasury to the credit of a fund thereby established for the use of the Board, which fund shall not be appropriated for any other purpose.

SEC. 16. The compensation of the secretary and other employees and the expenses of all members and officers of the Board, and all expenses proper and necessary in the opinion of the Board for the discharge of its duties, shall be paid out of said fund, when properly appropriated, upon the warrant of the Auditor of State, issued upon requisition signed by the president and secretary of the Board, subject to the limitations provided in Section 4 of this act.

SEC. 17. Every registered professional engineer or architect and every registered surveyor shall display his certificate in a conspicuous position in his place of business.

SEC. 18. The Board shall establish rules and regulations for administering its duties and carrying into effect the provisions of this act, but such rules and regulations shall not be inconsistent with any provision of this act or any statute of Ohio.

SEC. 19. Any person who issues, authorizes, signs, uses or presents any fraudulent evidence that he or any other person is entitled to receive a certificate, or swears to any false statement for such purpose or who fraudulently impersonates a registered professional engineer or architect or a registered surveyor shall be

guilty of a misdemeanor, and upon conviction thereof shall be fined in any sum not exceeding ONE THOUSAND DOLLARS and not less than ONE HUNDRED DOLLARS, or imprisoned in the county jail not more than one year nor less than 30 days, or both, at the discretion of the court.

SEC. 20. Any person practicing professional engineering, architecture or surveying in this State, as hereinbefore defined, in violation of the provisions of this act, shall be deemed guilty of a misdemeanor, and shall be fined not less than TWENTY DOLLARS nor more than FIVE HUNDRED DOLLARS, or shall be imprisoned in the county jail not less than 30 days nor more than one year, or both, at the discretion of the court.

SEC. 21. Such fine, when collected, shall be paid into the fund for the use of the Board.

SEC. 22. The secretary of the Board is charged with the duty of enforcing this act. If he shall have knowledge that the act has been or is being violated, he shall investigate the matter, and upon probable cause appearing, shall file a complaint and prosecute the offender. The Attorney-General of the State of Ohio shall be the Attorney for the Board. It shall be his duty or the duty of any prosecuting attorney, when requested by such secretary, to take charge of and conduct such prosecution.

SEC. 23. All acts and parts of acts inconsistent herewith are hereby repealed.

OTHER STATE LAWS, AND THE GROWING SENTIMENT AMONG ENGINEERS.

MANY States have passed such laws licensing engineers. In some States they have caused unnecessary trouble. Bills are before other legislatures now. Chemical engineers everywhere should see that their profession is properly represented and care taken of it.

The agitation for licensing of engineers first began in 1909, L. K. Sherman (Monad III, No. 12, p. 5). The opposition was strong. It was based upon such claims as: Not necessary if public

employs only members of high grade engineering socities. A license does not guarantee competency. Difficulty of defining engineering.

The advocate for licensing answered objections by pointing out that national society membership does not weed out incompetency. Licensing does bar flagrant cases. Licensing is not claimed to prevent poor judgment in selection of engineers by the public. Professions and trades now licensed have demonstrated to the legislatures and to the Supreme Court that licensing is desirable for the public.

Since then a favorable opinion has constantly grown. That the movement has come to stay is shown by such States as Michigan passing a licensing law.

In the State of Michigan, House Bill 505, File No. 338, was passed April 24, 1919. To avoid giving the bill in detail a paragraph of the points of interest to chemical engineers follows: The act provides for registration of "engineers"; regulates "the practice of engineering" as a profession; board of registration "shall classify applicants into respective branches of engineering as follows. . . . Chemical engineer"; provides certificates entitling holder to use title "registered chemical engineer," and "to practice in the branch of engineering in which such person is registered," provided that act not apply to railroad and other interstate corporations whose engineers confine their work to this corporation alone"; qualifications to be "six years practical experience under direction of registered engineer or equivalent thereto, "or who is a graduate in engineering of a college or school of recognized standing" and "who has had not less than two years' experience and shall pass a suitable examination by the board"; "time spent as a student of engineering shall be considered the equivalent of an equal amount of practical experience"; "board shall register engineers of other States or foreign countries to do consulting work in Michigan when they are recognized as consulting specialists in some branch of their profession and have had 10 years' such experience or when they have qualified under equivalent laws in other States or countries" with reciprocating provision.

S. B. Stilwell (Proc. Amer. Inst. Elect. Eng. 34, 635, 1915) states that there is a bill for licensing engineers, which he commends, that has been submitted to the governing bodies of national engineering societies. T. M. Haupt, Eng. Mag., Vol. 41, p. 310,

Criticism of Act to License Civil Engineers, states the proposed law is ambiguous and inconsistent, since it does not include all branches of expert service. And the "Board" is not amenable to people but appointed by Executives. If the engineer cannot make good he will be "weighed in the balance and found wanting."

L. M. Haupt, Licensing of Civil Engineers, Eng. Mag., Vol. 41, p. 956-8, gives an abstract of the model law drafted by the Committee of the American Society of Civil Engineers. The act is similar in detail to the Ohio bill already quoted. Haupt states that no legislation is needed, the public being amply protected if they will employ only those engineers who have demonstrated their ability.

Engineering News Record, Vol. 82, January 2, 1919, p. 67, states Louisville Association is to draft a bill for licensing engineers.

Engineering News Record, Vol. 82, February 6, 1919, p. 307, states Indiana Engineers seek license law with architects. Trying to avoid trouble that Illinois had with separate Engineer and Architect Laws.

Engineering News Record, Vol. 82, February 13, 1919, p. 349, states Engineers Council appoints a license Committee to inquire into proposed and passed legislation on the subject of licensing architects and engineers.

Engineering News Record, February 20, 1919, p. 402, states Oregon Engineers discuss legislation. Majority did not express themselves by vote as to favor the proposed legislation.

The Iowa Act includes as professional engineering all engineering practiced, the fundamentals of which are taught in engineering schools of recognized standing. Provision for civil, mechanical and electrical engineer on board but not for chemical engineers though Act includes the chemical engineering profession itself.

The Illinois Act of June, 1915, for structural engineers really covers chemical engineers with no provision for representation on the examining board.

The Florida bill of 1917 covers chemical engineering but makes no provision for representation of such on its board.

The Pennsylvania bill of 1913 was the same and mentions all the engineering societies except the American Institute of Chemical Engineers as responsible engineering organizations.

The writer understands that licenses are now required of en-

gineers in Illinois, Idaho, California, Florida, Oregon, Michigan, Louisiana, South Dakota, Iowa, Wyoming and Virginia. Bills have been prepared in Indiana, Colorado, Ohio, New York, Pennsylvania, New Jersey, Utah and North Carolina.

Engineering News Record, February 27, 1919, describes the various State laws on licensing engineers in detail and indicates where bills are being prepared.

J. M. Howe of Houston, Texas, states that "the Texas Association of Engineers is making a strenuous effort to have a License Bill passed by the legislature in June."

The American Association of Engineers, 29 South La Salle Street, Chicago, Ill., in its organ "The Monad," March, 1919, page 5 and Eng. News Record, Vol. 82, page 463, 1919, presents its standard license law by its committee on legislation as a model license bill. Its object is to render efficient service to the public, raise the standards of the practice, and promote unity in the profession. It is based on fourteen existing or proposed engineer's license laws. It complies with the fundamentals as formulated in the proposed standard law of the Joint Committee of Six National Societies headed by the American Society of Civil Engineers and reported February 4th, 1915.

Chemical engineering work is included in the bill though not named. No representation for chemical engineering is provided in the bill. It states the Board shall consist of three civil engineers, one mining or electrical engineer and the other one a mechanical engineer or naval architect.

The committee states:

"Whether we believe in a license law for engineers or not—and your Chairman is one of those who believes in it—the fact is that there are five or six States already with established engineers' license laws, there are half-dozen more States in which State legislation is now being planned for such an act and there are still other States in which it is being formulated and is bound to come. In view, therefore, of the rapidly crystallizing sentiment in further favor of engineers' license laws, it is highly important that the engineering profession now promptly agree upon a fundamental law and uniform interstate reciprocity arrangements."

In Ohio the sentiment is not all one way. The Cleveland En-

gineering Society (Maurice Warner, Chairman Committee on Legislation) states chemical engineers opposed to any law but if there is such, they wish to be included also; electrical engineers appear mildly opposed and architects in favor of licensing. Suggests bill apply only to State office holders. So far as able to learn, "general sentiment among engineers and architects is favorable to a license law. The exception is the chemical engineers who are opposed to any law for this purpose."

Whatever the opinion of the chemical engineer may be upon the merits of the matter at issue, the above citations show the drift towards license laws in some form. It becomes the business of the chemical engineer to take part in the movement in the individual States or accept the consequences of leaving his interests in the hands of civil engineers who have drawn up most of these bills. These engineers recognize that the American Chemical Society is scientifically altruistic in its membership requirements and hence rightly makes no professional membership requirement and these engineers do not on the other hand know of the existence of The American Institute of Chemical Engineers, so that the chemical engineer is usualy left out of consideration though his professional work is seriously affected by every bill which the writer has read.

The thanks of the writer are due to E. G. Bradbury, retiring president of the Columbus Engineers' Club and Chairman of the joint Committee on the draft of the Ohio Bill for use of his correspondence file on this subject and to P. E. Marling, Instructor in Chemistry, The Ohio State University, for the references to the Engineering News Record.

Laboratory of Industrial Chemistry
The Ohio State University,
Columbus, July 16, 1919.

CHEMISTS SHOULD NOT BE LICENSED.

By A. W. SMITH

Read at the Boston Meeting, June 20, 1919

Mr. President, and members of the Institute, I want to say, to start with, that I agree with what Doctor Withrow has said. His contention is right. There is a real danger that the bills being introduced in the various State Legislatures may do us damage, and we should be on our guard. This bill that Doctor Withrow mentions contains a clause that would make it illegal for a Chemical Engineer to make any drawing even of a ditch for commercial use. If you should want to do any work in your chemical plant under such a law, you must employ a registered engineer to do it for you.

My contention is that this whole matter of the trouble from incompetent engineers in the Government service can be taken care of very easily by simply passing a law that would require all Government employes or Government engineers to be examined or licensed. That would leave the rest of us free, and that is perfectly proper. But that we should put ourselves under the control of a partisan Government official or Board seems to me wholly without necessity or reason.

I will mention but one or two points in the paper just read. I think Doctor Gudeman's argument answered itself to a large degree. The idea of unionizing chemists is an obnoxious one to me. I don't want to join the American Federation of Labor. The whole idea of unionizing brings all to the level of the lowest. You simply bring the whole profession down legally to the point of the very lowest in ambition, ability and attainments. It takes away initiative, and all idea of progress, as it has done in the Labor Union. The Labor Unions are devised to stifle meritorious progress, and they do it very effectively.

The first paper was directed to the idea that we need publicity, and public recognition. Personally I have never felt that need and do not now. It seems to me that we have been recognized in the past five years; that we now stand on a pinnacle so high that we do not need further recognition, and I don't think that unionizing would give us that recognition.

All the bills that I have seen simply propose to license all graduates of chemical institutions, no matter what kind, just as the doctors and lawyers are recognized by registration or admitting them to the bar if they have a diploma. What change will that make in our status? We shall be in the same position as before except that we will be subject to the petty domination in many respects of a politically appointed official.

This thing has been in vogue with physicians for a long time, and what has it done? The old saying among the lawyers was, in speaking of expert witnesses, referring to medical experts for damages in personal injury cases, that there were three classes of liars: liars, damned liars, and the expert witness. The licensing of the doctors in those days did not change their character or fairness at all. They were just as reliable as before. And it will not change the status of the chemical profession.

In regard to this Ohio bill, I have asked many of my engineering friends, including Doctor Withrow, what the purpose of it was, and what good it would do him. The only argument for it was this about county surveyors. We don't need to license chemists in order that we might have good county surveyors. It is very far afield. But if such bills are enacted in the various states, we shall have to be on our guard. We could not build a house without employing an architect, and the architects under such laws will be able to prevent other people from drawing designs of even a sewer across the plant. If such bills are passed, of course the chemist should be included with them, or he will be in trouble.

The idea that state licensing or registering of any kind would change our status is remarkably unlikely. It seems to me that our status is based on reputation. It is good work that brings us before the public. Reputation and training and experience are what make our standing, and not a Government license. Let your good works shine and you will have recognition and reputation. Doctor Gudeman mentioned the case of a Chicago newspaper that failed to see the difference between a chemical engineer and a

physician or biologist. That was in Chicago. I am sure that the intelligent press of Boston would not make any such mistake.

Dr. GUDEMAN. You will except Harvard University, won't you?

Mr. SMITH. I will except every place except Chicago. Doctor Gudeman says that the profession deserves the scientific protection of licenses. I don't see that there is either science or protection in it. Better deal with the matter ourselves. We are a rather democratic institution, the American Institute of Chemical Engineers, as well as the American Electro-Chemical Society and the American Chemical Society, and we can take care of this matter of the charlatan. If we are under the domination of a Government appointed official then we tend toward Prussianism—the autocracy that we have just escaped from. And to maintain true democracy in this matter is the only way to eliminate the charlatan and fraud among ourselves. (Applause.)

SOME OBJECTIONS TO THE LICENSING OF CHEMICAL ENGINEERS.

By DAVID WESSON.

Read at the Boston Meeting, June 19, 1919

On reading through Dr. Gudeman's paper it seems to me there is very little reason for changing the one which I had already prepared for this meeting.

After putting Dr. Gudeman's paper through a condenser, it seems the chief object of the expedition is to make an attempt to have our profession recognized and to receive legal standing. I believe the best way to make our profession recognized is by doing good work, or rather doing things of such value to the public that our profession cannot escape recognition. I do not any more believe that legislation can make our profession stand better in the eyes of the community than Congress can legislate silver to be on the basis of 16 to 1 with gold or permanently fix the price of wheat at $3.50 a bushel.

Dr. Gudeman uses as one of his arguments the case of a man who refused to trust any chemist to analyze his product and seems to draw the inference that the man's distrust was because he had no confidence in chemists. I would be more inclined to believe that it was because the chemist would show up something the man did not want shown. Do you suppose this man would have any more confidence in a chemist if he were licensed? I think his case is very much like that of the Christian Scientist and physician. Regular physicians are licensed and registered but where is the Christian Scientist who is going to trust them?

Perhaps in the state of Illinois, where Dr. Gudeman comes from, some of the corn-fed lawyers and judges with whom he comes in contact do not know what chemists are and what they can do for the community, but taking the country at large, I fail

to see the necessity or desirability of having our profession put in the licensed class.

The paper which I had prepared to read is as follows:

I never shall forget a little incident which happened in Hamburg a year or two before the war. Having rather a short margin of time to make a train, and seeing nobody in the ticket office, I whistled badly, with the result that an irate Fräulein quickly appeared from the inner recesses and greeted me with the words "Nehmen Sie mir für ein Hund?" which, for the benefit of those who have relegated their German to the scrap heap, means in plain English, "Do you take me for a dog?" It needs the German accent, however, to convey the right feeling of indignation, which is difficult to translate.

When I received our Secretary's announcement that two papers were going to be presented on the subject of licensing chemical engineers, I felt very much like the aforesaid Fräulein.

At home I have a most amiable little Scotland terrier named "Mutsy" who satisfactorily performs all the functions of a dog inasmuch as she trees all the cats and squirrels on the place, drives away strange dogs, never bites anyone, and is the most affectionate and harmless little animal that ever lived, yet because some other dogs kill sheep and commit various atrocities, Mutsy has to be licensed and her owner has to pay a tax therefore. Now I object to being placed in the dog class.

The other day I had a man working on the connections of the hot-water heater in my house. He rigged up the thermostat in such a manner that when the water reached the proper temperature instead of shutting off the draft and holding the fire, more draft was thrown on and serious trouble might have resulted had I not looked the job over myself. That man was a licensed plumber, with the accent on the License. The license was issued, I suppose, so he could perpetrate bad work and collect big bills for it.

We have all of us at some time in our lives bought fruit from peddlers, who were duly licensed. That did not make the fruit any better, did it?

Dentists have to be licensed; they ought to be. Some of them commit atrocities which would never be tolerated except at the hands of a licensed practitioner.

Druggists are very properly licensed before they are allowed

to make up prescriptions, but how about the physicians who write the prescriptions? They are licensed, but they are human and make mistakes same as other mortals, and their patients or their patients' heirs, executors and assigns have to pay for the mistakes just the same.

The mere fact that a man has been licensed to practice a trade or profession means little and does not improve the man's standing in the community. The licensing of saloon-keepers has not added to their reputation or the reputation of their profession. The mere fact that a man needs a license to practice his chosen work is an implication that either there is a chance for dishonesty or danger to the community in allowing unlicensed people to practice various trades or professions, or else the licenses are issued for the purpose of obtaining revenue as a means of taxation, as in the case of some states taxing commercial travelers, insurance agents, etc.

Now as a chemical engineer, I protest against any more taxes than I am paying now. If there are any members of our Institute who are not satisfied after having paid their dues and received a membership certificate and the Institute pin that they are fully qualified as chemical engineers, and want a state license besides, they should resign at once and join the plumbers' union.

When a man has run the gauntlet of our Membership Committee, he has passed through a closer scrutiny than could possibly be expected from any politically appointed state board of examiners, and his membership in the Institute is a far better voucher for his professional standing than any license that could be issued.

Gentlemen, let us not for an instant demean our profession by seriously considering the placing of it in the licensed class.

DISCUSSION.

The President: We have just a few moments for discussion.

Dr. Langmuir: Professor Smith's remarks advising scientific men to stay away from the Union brings to my mind the fact that the Bureau of Standards and other Government Bureaus have all joined the American Federation, and at the Atlantic City meeting

of the American Federation of Labor last week a paper was read by Doctor Hillebrand of the Bureau of Standards.

As a plant superintendent I have always fought union labor, and we have had no union labor in our plant to date. But they have broken in now, and last week we signed up with the Drivers' Union.

We feel in New York that union labor is coming, and we have to cope with it, and that all of our plants will be unionized in the next few years. If scientists holds themselves aloof from labor organizations, they lose an opportunity to do a great deal of good.

The paper presented by Doctor Hillebrand was on the proposition of joining the unions, in other words an effort toward conciliation and co-operation on the part of scientists in meeting the union labor movement, which is here to stay. We can not only improve union labor but may ourselves be improving the condition of the public by co-operating with them, and if necessary, joining their unions. I don't feel that we ourselves will be hurt, but that they and indirectly the public will be benefited.

Doctor GUDEMAN: I am very sorry now that I had to abstract my paper as I read it because I see that members have drawn false conclusions therefrom. I agree absolutely with Doctor Wesson that if we could have the recognition and standard given by this Institute, this would be satisfactory. But take other chemical socities in the United States and abroad. Have they any standing at all? What are the requirements, except in this Institute? Nothing except the inclination and the ability to pay the dues. It makes no difference whether you are a chemist or a doctor. They don't know whether you are dead or alive, as long as you pay your dues, and as I have stated in my paper, chemical societies, with or without codes of ethics, are not sufficient, and carry little if any weight, attach no responsibility to a professional chemical standing, and are no indication as to ability or integrity. I say this with full recognition that our Institute requires scientific standing to enter it, and also has a splendid code of ethics, seldom made use of. But you know too well that many of our fellow-chemists sneer at both, and that numerically we are not strong enough to make any great impression, but we can initiate a move to bring about a proper recognition of the chemical profession. Perhaps we should not do so, for although many of our members

are chemists, still as members of the Institute we are chemical engineers, one of the professions with the chemical adjective partly recognized.

Now, for example, if anything occurs in reference to the professional ethics of a chemist, all we can do is to ask "How can you stop the recurrence of it?" If it was done by a member of the Institute, we could expel him from the Institute if any violation of our code of ethics should take place, which so far has never been done.

As far as unions are concerned, I do not agree with Doctor Smith at all. I ask whether he considers any one of the recognized scientific professions as being unions. It makes no difference which one of the recognized professions you take, as far as the diploma is concerned. In many States you are a lawyer by being admitted to the Bar. A diploma in medicine does not give you the right to practice. You have to pass the State examination. As to publicity, I do not ask for publicity. We are recognized as having done something in the last four years, because we are recognized as having done as much as any other scientific profession, and perhaps more than any other, when you take into account our antiseptic treatment and all other chemical treatments. I do not ask for publicity, but for recognition. I say, give us some recognition whether it is license or patent or anything else. But we ought to have some standing, a legal recognition, so that the chemist can stand before the public as a chemist.

The President: I find it difficult to follow the workings of Doctor Gudeman's mind. He takes the position that if the societies all had a code of ethics such as the Institute has, that would meet the objection.

Doctor Gudeman: A standard for entrance.

The President: And I recall very distinctly at the time when I was chairman of the Committee on code of ethics of the American Chemical Society the most violent opponent against that code was Doctor Gudeman.

Doctor Gudeman: I think you are mistaken there.

The President: I have the correspondence.

Doctor Gudeman: I objected to the code of ethics being made in the way it was, compulsory. My objection was that you forced in a code of ethics that you could not enforce, but I have changed

my mind since that time, and accepted the action of the majority by compulsion.

The SECRETARY: I want to say two things. I have appeared as a witness in Court a good many times and it seems to me that this discussion is largely on that point. I have never found any difficulty. The Court asks for degrees in college, and your position, and they let it go at that, and all other chemists I have observed on the witness stand have qualified in the same way. Membership in the societies is mentioned also, but the difficulty is met in reference to the American Chemical Society that it has no particular standards, but this Institute has standards of membership and when that is stated in Court I have never found any great difficulty and I have never seen a case where in my experience licensing would have helped. I have seen cases, several of them, where a man has appeared as an expert and has been thrown out, and where lawyers have succeeded very well and quickly in showing that a man did not have the necessary experience and training, and his testimony has been thrown out.

Doctor Langmuir has introduced a different phase of the question, and that is the joining of the labor union, or forming a union of chemists and scientists. I think they are two separate propositions. I agree with Doctor Langmuir and also in one phase of it with Doctor Gudeman, that the movement is gaining ground for something of this kind, and these States which are passing laws are bringing it about. I believe it is coming. It looks to me as if it is what we will have to face. And if laws are going to be passed of this type, what stand should we take in reference to them? I don't know that we can prevent it. Something is going to be done.

With reference to the labor unions, that is another thing that is coming up, and both of them are fairly large questions. I am not in favor of the formation of labor unions by chemists and scientists because the tendency of labor unions is to discourage initiative and reduce production by establishing a uniform wage which must of necessity be an average wage. This deprives the energetic and capable man of the reward of his superior ability. As the most important work of the chemist is the improvement of processes for which no standard compensation can be fixed, labor unions would lower the efficiency of chemists and in the end lower the compensation instead of increasing it. I am not opposed to

labor unions of the right sort for mechanical work, but am strongly opposed to the closed shop because it is un-American and despotic, denying constitutional rights to American workmen. It also reduces output and discourages efficiency.

Licensing is a different matter, and I think that it is taken care of by the present methods of qualifying chemists.

The PRESIDENT: I am sorry that we shall have to cut further discussion short in order to give Mr. Russell an opportunity to present his paper. I might just say and I believe it is the experience of every one of us who has come in contact closely with union labor—that I should be sorry to feel myself or see my brothers in the position in which these men are placed in reference to their council. It is almost pitiful, their fear that they might in some way ovetstep some rule of the union, and be called to the office and fired.

REPORT OF COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

June 18, 1919

The American Institute of Chemical Engineers:

Gentlemen:

The war naturally absorbed the interests and energies of the members of the Institute so thoroughly that little was left of enthusiasm for the education work of the Institute by any of us. The uncertainty of the so-called reconstruction period, if that is what the present period of auto-government is, seems to have the same lethargic effect.

Your committee attempted to galvanize the patient at the Chicago Meeting by prescribing the old-fashioned remedy of a little work. In fact, we did not merely recommend, we subtly brought pressure to bear and secured a " promise to pay " from the Institute, as you will see when we quote you from our report on Chemical Engineering Education as adopted at the Meeting of January 15, 1919, as follows:

> " We ask that the acceptance of this report be construed as instructing the Secretary to take a census of those attending this (Chicago) meeting who desire a copy of this Carnegie Bulletin and to send out a return mail card asking the membership to give the requesting of a copy of this bulletin (The Mann Report) their immediate attention."

Our report, as a whole, was adopted without modification except that suggestion was made from the floor by Dr. Gudeman that the return card bear certain extracts from the introduction to the Mann Report calculated to arouse interest in the same.

Was it a Scotchman, or an American forerunner of the thrift-stamp period, who visited a physician and was advised to take certain precuations, among them abstaining from liquor? When the patient arose to go, the physician suggested that he was in the habit of charg-

ing for his advice. To this the retort was made " I'm not going to take your advice."

As the patient in the story said, so our patient has done, and we were not even entitled to a fee. Few of our members, as far as we can learn, have obtained the Mann Report.

Your chairman was not present at the final business meeting in Chicago, but we understood that the census we asked for was not taken. It was probably crowded out by the ardent discussion of the resolutions on dyes and industrial readjustment after government war domination.

The message urging the members to procure the Mann Report and be prepared to discuss it at this meeting in Boston was not sent out until the program for this meeting was issued (about June 1st). The issue of bulletins containing the minutes of the Institute Meetings and Committee Reports are themselves naturally slow. That for the Chicago meeting with our previous report on education is not yet issued at this writing. The great body of the members, therefore, have been given no intimation of our desire to have them study the Mann Report with the object of making its discussion a feature of this Boston Meeting as was recommended in our Chicago Report. This being the case, the Secretary was justified in not providing space in his well-crowded program of this meeting for a special discussion of the Mann Report.

Under the circumstances, your committee again prescribes the only remedy worth while—work. Therefore, we now repeat the request and recommendations of our previous report.

The object of your committee may not have been understood. It was our desire to have the membership thoroughly familiar with the Mann Report so that a final discussion of the same could be made a special feature of the program, of an early meeting of the Institute. The committee requested that *a return mail card* be sent out requesting application for the Mann Report as a method of drawing the war interest back to education. With perfectly good intent, this proposal was modified from the floor of the meeting by way of expansion to emphasize the scope of the Mann Report. This perhaps robbed us of the action value of the return mail card and eventually the request for action came out with other important matters, the very thing we wished to avoid. We want to focus attention on education by a communication solely on that subject.

We have asked the Secretary to provide a sheet at the registration

desk of this Boston Meeting, headed *Sign here for copies of the Mann Report on Engineering Education*, and have asked that the registration official request each member who registers to affix his name to this list if he has not already received the Mann Report.

An effort was made by the committee to have Dr. Mann himself address us briefly at this meeting as it was understood that he would be in Boston. Word had not been received from him up to the time of program going to press.

We ask, therefore, that the adoption of this report operate to instruct the designated officers.

1. That at each session of the Boston Meeting for business or otherwise, the Secretary of the Institute circulate a sheet for signature of those who have not yet received the Mann Report and that the president of the Institute or the Chairman of each session call the attention of these in attendance at the session to the circulation of the sheet and to the desire of your committee for a complete record of those who desire a copy of the Mann Report.

2. That the Secretary of the Institute be instructed to request the Carnegie Foundation as soon after this meeting as possible to send the Mann Report to those whose names appear upon the census sheets distributed for that purpose at this general meeting.

3. That the Secretary of the Institute send a return mail communication inviting application for the Mann Report to those members not listed in the census or who have not otherwise applied to the Secretary for the Mann Report and that such return communications be sent out alone and not with other mail matter of the Institute as a special communication on education.

And finally, we ask

That your committee be authorized to send out through the Secretary's Office, a questionnaire to the membership upon the Mann Report as soon as it is somewhat distributed should the committee find such a procedure desirable.

Respectfully submitted,

James R. Withrow, Chairman.
J. H. James.

Since the above was submitted to the committee the Bulletin of the Chicago Meeting has been issued. A reply has been received from Dr. Mann stating that he was not at the Massachusetts Institute of Technology as had been planned, but was still in the War Depart-

ment Educational work at Washington, D. C., and regretted his inability, therefore, to address the Institute in Boston as your committee had planned. The committee's urgent request to the membership concerning the Mann Report is attached for emphasis.

JAMES R. WITHROW,
Chairman.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, OFFICE OF THE SECRETARY

May 29, 1919.

The following communication is sent to members at the request of the

COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

The American Institute of Chemical Engineers voted at the Chicago Meeting that each member should read the Mann Report.

Write to-day (not to-morrow) for a copy of the *Mann Report on Chemical Engineering Education.*

Address *The Carnegie Foundation for the Advancement of Teaching, 576 Fifth Avenue, New York City.* Stating that you are a member of the Institute.

Do this to show the Carnegie Foundation your personal interest in Chemical Engineering Education.

Our institute has always been interested in this vital matter. We are all agreed in one particular. We want to improve Chemical Engineering Education for the benefit of our successors, our country, and because we employ the product of the Engineering schools.

We want, each man of us, to be better informed on the status of Engineering Education in this country so that we can hammer the wiser at our subdivision of the work.

The schools need our help. Many of them want it.

By motion of Dr. Gudeman it was requested that the following quotation from the Mann Report be sent you so that you could see the value to you of reading this Mann Report:

"In this half century that has passed this course of study has been overlaid with a great number of special studies intended to enable the student to deal with the constantly growing applications of science to the industries. While the original teaching plan remains as the basis of the four-year engineering curriculum, the courses given in most schools have been greatly modified in the effort to teach

special subjects. As a result, the load upon the student has become continually heavier and bears unequally in different places and in different parts of the course. In addition there is a widespread feeling that under this pressure the great body of students fail to gain, on the one hand, a satisfactory grounding in the fundamental sciences; and on the other hand, do not fulfill the expectations of engineers and manufacturers in dealing with the practical problems with which they are confronted on leaving engineering schools."

"The Report is published by the Carnegie Foundation as a work of cooperation with the great engineering societies, and with the hope that the formulation of these enquiries and their discussion may lead to a serious effort on the part of those having to do with engineering education to reexamine the curricula of the schools, and to approach the problem of their improvement not only from the standpoint of the teacher, but also from that of the practicing engineer and of the employer."

In accordance with the vote at the Chicago Meeting, the Mann Report will be brought up for discussion at our Summer Meeting, It is for this reason that members are urged to secure a copy of the Report so as to be prepared to discuss it at our Summer Meeting.

JOHN C. OLSEN,
Secretary.

Dr. WITHROW: Since this report was written, and sent to the members of the Committee, Dr. Mann has replied that unfortunately he would not be in Boston. The Massachusetts Institute of Technology, with its usual activity and foresightedness, had arranged with Dr. Mann to join their forces; but Dr. Mann is still at the War Department and therefore canot attend this meeting. In addition to this, I have, myself, personally visited the office of the Carnegie Institute, to keep them interested in sending us copies of the Mann Report, and they have promised to do so.

The PRESIDENT: Gentlemen, you have heard the report of the Committee on Chemical Engineering Education. Is there any discussion? If not, and there is no objection, the report will stand accepted with its recommendations.

ENERGY IN THE REALM OF RECONSTRUCTION.

By CHESTER G. GILBERT.

Read at the Boston Meeting, June 19, 1919.

BEFORE perpetrating the crime to which I have just been assigned, I would like to emphasize the fact that it was wished on me by Doctor Little, and is not of my own choosing. Still, overworked and abused though it is, I think you will all agree with me and with Doctor Little that it is none the less a distinctly live issue, that it is unquestionably the livest issue in the world to-day.

We are only now coming to realize that reconstruction means more than reversion to the old established order of co-ordination and price adjustment; more than resetting and building afresh on old foundations; that in one way or another the foundations themselves have been very materially altered in the course of the past four years. There are still those averse to regarding the changes as fundamental or as other than in the nature of a passing manifestation. I met one just the other day in the secretary of a large corporation which normally employs several thousand hands. This is only to be expected for there is always a numerous group whose only conception of the relationship between time and motion would seem to have been gathered from contemplating the pendulum of grandfather's clock. They forget, in the present instance, that the Great War was waged for the very purpose of asserting social and economic changes of a most far-reaching order; and that social and economic conditions in turn provide the foundation of industry.

In the world war, whatever its inception, the forces of democracy were ultimately lined up solidly in a life and death struggle against those of autocracy, and the latter in going down took the props from under what it was supporting the world over. We begin to sense something of the meaning this has for us as soon as we stop to consider the complexion of our industrial labor

supply. Roughly, three-quarters of our unskilled mine, mill, factory and construction labor is foreign born and bred in environments of autocracy. This, our unskilled mass labor supply, is autocracy's contribution to the democracy of Americanism. Autocracy, be it recalled, holds to ignorance, to subservience, to social repression; democracy, on the other hand, makes for education, for freedom of opportunity, for social consciousness. In educating to fitness and the desire for better things and throwing open the doors of opportunity for their attainment, we have ignored the needs of industrialism, the modern scheme of civilized existence. We have been living the inconsistency of combining an economic need for ignorance with a social focus on its effacement. Ours has been the position of the man at work sawing off the limb of the tree on which his ladder rests—all fine and lovely until the job is done.

We finished the job last November; since then we have been in the air. The question is, where are we going to land? Is the work of social readjustment on foot in Europe to result in projecting renewed support? Are we to pass on and have recourse to finding support in the over-population of Asia? Or are we to come right down to earth and re-establish our support on an altogether different basis?

It is not to be expected that the repressed European peoples from which we have been drawing for our industrial labor supply, will find their social and economic status so greatly bettered as a direct outcome of the war, that this country will have lost its power of attraction. But the question is not one of quantity alone. It involves quality quite as well as quantity; how well content, how tolerant the immigrant class of the future will be with the place reserved to it in the past. In this connection the social changes wrought in the furnace of war during the past four years are of the utmost practical significance.

We, who have long, long since passed through it all, have watched the development of social consciousness abroad as from the grandstand. We have watched it burst the rotten fetters of Russian absolutism and in the sudden sense of unaccustomed freedom start on a rampage from which it has not yet subsided; we have watched it eat away the iron ring of Prussianism from within; even as it was being battered to pieces from without; we have watched it assert the rights of a dozen subject nationalities; more recently and more significantly still, we have seen it soberly and

constructively at work on the enormous task of remodeling the economic imperialism of England.

The other day I read an article by one of our foremost financiers, in which he traced the development of social consciousness in England, figured its meaning in terms of increased cost of production, and concluded that under this handicap England was due to surrender to this country her position of supremacy in world trade. Unfortunately, however, he left us in the dark as to how we in turn are to maintain a static basis of costs while that of England advances. This, I think, is rather typically expressive of our American attitude toward the social developments in Europe. We are disposed to disregard the fact that aside from the negro our unskilled mass labor is well-nigh wholly born and bred in that seething caldron of European social upheaval; we are disposed to overlook to what extent Russian absolutism, Prussianism, suppressed nationalism, and the lesser evils of Europe's past have contributed to solving our own problems of the past. We, over here in the grandstand of democracy, would do well to give serious thought to this phase of our American industrialism, and for those of us who have been sitting back, confidently waiting the counter swing of the pendulum, there is a further item of food for reflection. Public opinion may change over night by a process of substitution, but public consciousness, social consciousness, whatever its form, is a matter of evolutionary development. It does not change by substitution any more than you can change the ears of a donkey, however incongruous they may seem, into those of a horse.

Our immigration for the past five years has been practically cut off and even now as we talk of expansion, we are some twenty or thirty per cent subnormal as to labor equipment. Worse than that, looking ahead, our old line industrialism is between the devil and the deep. Other repressive political forms may renew our industrial labor supply but in proportion as they do, they will still further foster the extremism born of repression in the past, an extremely dangerous source of reliance even to the extent of meeting our direct needs, let alone those of expansion in the interest of world trade. Cut it out or prune it down by rigorous immigration laws and will our Americanized labor be content to descend the social scale and fill the position at the bottom hitherto left to the un-Americanized immigrant? The question needs no answer.

It has been suggested, and the suggestion has even found lodgment in a Government publication, that the situation might be relieved by opening the doors to admit the entry of a certain number of Asiatics, presumably on something of a parity with the social status of the negro in the South, but such a step is too unthinkable for serious consideration.

While we have been absorbed in watching the progress of events abroad, we have been rounding the turn where we must shortly face the lack of social and economic adjustment at home, where the chorus of voices now so fatuously decrying the extremism of our un-Americanized labor, and in the next breath proclaiming the promise of supremacy in world trade, will be silenced. And instead of waiting for the counter swing of the pendulum that is not, we will get down to the work ahead, the work of fundamental economic reconstruction based on the democracy of Americanism unsupported by any props of autocracy abroad and uncontaminated by any of the social diseases to which it has given rise.

When we do we shall find confronting us an American situation differing in no wise materially from that which we see so clearly threatening the supremacy of England's industrialism to-day. It is not entirely home-grown as in England's case, and it is not so acutely developed, so it is less apparent; that is all. But here, quite as well as abroad, the war has condensed within the lapse of five years the normal social and economic advance of fifty. This sudden advance of democracy has left industry far behind. The problem is how to catch up, not how to get still further back to the position of five years ago.

The outstanding feature of this advance is in the standard of labor; and the problem is just as outstandingly that of compensating for the increased cost of the human factor in the work of production. The consumer unfortunately is disposed to harbor the idea that this compensation must come, be extracted if necessary, from the pocket of the producer. The producer is just as unfortunately disposed to believe that it must come, be extracted if necessary, from the pocket of the consumer. There is no choosing between the two. In the one may be seen the germ of economic disaster; in the other the germ of social disaster and each in turn amounts to the same thing in the end.

Right here it would seem lies the main point of difference with respect to the American situation. The difference is one of atti-

tude, not of fact. England has accepted the permanent evolutionary character of the development, and has faced the issue squarely, recognizing that neither world trade abroad, nor social adjustments at home, are to be maintained through the subterfuge of increased cost whether to the producer or to the consumer.

American industrialism, on the other hand, has unconsciously dodged the issue by employing the expedient of increased cost under the assumption that the existing labor conditions are due to pass. It has been enabled to do so successfully, however, only by virtue of the broken international commercial relations. Once the break is fully repaired, we cannot build up trade abroad on any such basis any more than England can hold it; nor can we quiet the growing discontent over the cost of living at home.

The situation is not so acute as it is in England, which lives by manufactures and international commerce, but it has serious potentialities for us, just the same. Fortunately, too, it is not a new one. All along at every turn in industrial expansion we have been accustomed to face the problem of an advanced and steadily advancing labor cost, and we have solved it in the only way that it can be solved—by increasing the effectiveness of the human factor in production. (Applause.)

Taken five years ago, industry could not afford to employ the working methods of fifty years back. No more can the reconstructed industrialism of to-morrow afford to employ labor in the pre-war capacity of yesterday. Instead there has got to be a tremendous conserving development in eliminating waste effort and furthering the employment of mechanical means, in co-ordination and power.

Toward this end we would do well to take a leaf from the lesson England is now feverishly learning, and give special heed to the development of our energy resources, coal, oil and water power. They certainly need it. The most important of all the resources in their bearing on the possible development of democratic institutions, they are the most neglected, the most abusively wasted. Petroleum has been mined on an appallingly wasteful basis of extravagant competition, until there is reason to believe the peak of production has been reached. Our coal, though more plentiful, is treated with a similarly wasteful lack of co-ordination, both as to mining and as to use, making the working cost of energy double or treble what it ought to be. Our natural gas supply, nature's

bonus, has been squandered away as probably no other resource ever was in the civilized world. Finally, our water power administration can be fittingly described only as a joke. We have been devoting a lot of time and space to the need for Americanization. Permit me to commend the adequate development and utilization of our energy resources as the most potent influence toward Americanization in the face of social derangement anywhere to be found to-day. (Applause.)

The President. Gentlemen, I feel that we have been greatly privileged to listen to this brilliant and suggestive paper by Mr. Gilbert, and I should be very sorry to say anything that might turn your thoughts from the impression that he has left in your minds. I can therefore only express the hope that we shall see you all to-morrow night at the Brookline Country Club. (Adjournment.)

MANUFACTURING PLANT OF THE PROVIDENCE GAS COMPANY

By WALTER M. RUSSELL

Read at the Boston Meeting, June 20, 1919

The City of Providence, Rhode Island, U. S. A., is located at the head of Narragansett Bay, about thirty miles from the open ocean. The city proper has an area of something over eighteen square miles and a population within this area of about 250,000. As a seaport, it ranks tenth in the United States in bulk of tonnage and value of cargoes, having direct connection by water with Philadelphia, Baltimore, Norfolk and Mediterranean ports. It is the leading oil port of New England and with the completion of a new thirty foot channel will have one of the best harbors in the world.

Providence is a great manufacturing city, being first in the country in the manufacture of jewelry and silverware, also having the largest mechanical tool factory, file factory, engine factory, screw factory and silver factory in the world. It is surrounded by the greatest textile districts of the country.

Gas is supplied to the city proper, also to Olneyville, cities and towns of North Providence, East Providence, Cranston, Riverside, Barrington, Warren and Bristol, serving in all about 65,000 consumers, utilizing some 450 miles of mains.

Being the center of a great industrial section and known as the "southern gateway" of New England, it is the logical point for the distribution of gas and coke to industries requiring these commodities.

History of Development

The Providence Gas Company first commenced operations in the year 1848. A coal gas works was erected on the east side of the Narragansett Bay and became known as the East Station. This gas works continued in operation until the year 1870, at which time the output of gas was about 132,000,000 cubic feet per year.

In 1870 a new gas works was built on the west side of the Bay, called the West Station. (Figure 1.) This plant was considered a model for its time and it was in this works that some of the first recuperative benches in the United States were successfully operated. Coal gas only was made in this plant until the year 1891, when water gas sets were installed.

In 1877 the Citizens Gas Company began operations in opposition to the Providence Gas Company. During the 70's there was a great deal of activity in the United States on the part of opposi-

FIG. 1.—North Station from a Drawing by E. Goucher, 1870.

tion gas companies. These were usually organized by promoters for the purpose of putting up a plant which would later have to be bought out by the established company at a profit to the promoter. As a rule, these companies put up cheap water gas plants but in this case, there was an exception, as the Citizens Gas Company built a coal gas plant which was purchased by the Providence Gas Company in the year 1878 and became known as the South Station. In 1890 water gas sets were built in this works. The West Station then became known as the North Station, and these two works, the North Station and the South Station, continued in active operation, making coal and water gas, until the year 1911.

Between 1900 and 1906, the output of gas increased fifty per cent. and in 1905 it became evident that the capacity of these sta-

tions would soon be exceeded; also both the North and the South Station were situated where adjoining land was extremely expensive to purchase and the land already owned was so closely covered with buildings as to allow of no further expansion. It was, therefore, determined to plan for the future, and forty acres of land were purchased situated about two miles southerly from the town, bordering on Narragansett Bay and having a railroad connection with the New York, New Haven and Hartford Railroad. During the next four years, many plans were carefully considered, which culminated in the construction of an entirely new coal gas plant at the new site, which became known as the Sassafras Point Station.

In 1910 the North Station was abandoned and the following year, with the starting of the new coal gas plant at the Sassafras Point Station, coal gas was discontinued at the South Station, it being continued only as a water gas plant. The output for the year 1910 was 1,386,819,000 cubic feet.

In January, 1909, a contract was let to the Didier-March Company to build a retort house complete from the coal crusher to the coke storage bins; the retort house to be capable of housing four batteries of retorts, two only being built at first. These batteries each consisted of six benches, containing ten retorts, making one-hundred-and-twenty retorts in the first installation. This was followed by a third battery of sixty retorts in 1911, and in 1912 a fourth stack was built of six benches, each containing fifteen retorts; so that the total capacity of the house was two-hundred-and-seventy retorts. The construction of the coal handling equipment, condensing and purifying buildings and equipment and the meter house and power house equipment was done by The Bartlett-Hayward Company.

Ground was broken April 1, 1909, and the first gas was made in October, 1910. The system of coal carbonization adopted was the Dessau Vertical Retort slightly modified to meet American conditions. The plant as finally completed had a nominal daily capacity of 3,200,000 cubic feet. This plant continued in operation until January, 1919, when the retorts were abandoned and a battery of forty Koppers Combination Gas Ovens was turned on.

In 1916 a new water gas plant was built at Sassafras Point and all manufacturing was abandoned at the South Station, thus bringing all the manufacturing plant together at one works. In 1905 a

4,000,000 cubic foot holder was built near the South Station. In 1911 a 6,000,000 cubic foot holder was built at Sassafras Point and in 1915 a 3,000,000 cubic foot holder was built in a suburb of Providence for reinforcing the supply in that district. All holders were built by The Bartlett-Hayward Company and are telescopic holders contained in steel plate tanks on concrete foundations.

During 1917 it became apparent that the vertical retort plant had reached the end of its useful life, and various plans were considered for replacing it with coal carbonizing equipment. It was finally decided to build a battery of forty Koppers Combination Gas and Coke Ovens, which would give a nominal generating capacity of 7,000,000 cubic feet per day, capable of making at least ten per cent. more gas than their rating, if desired. The construction of this plant was started early in 1918 and gas was first made the latter part of January, 1919.

At the present time the Providence Gas Company is equipped with a water gas plant which can easily generate 9,000,000 cubic feet of gas per day and with a coal gas plant generating up to 7,750,000 cubic feet per day. As the present output is in the neighborhood of 2,250,000,000 annually, with a maximum daily output of 9,300,000, it would appear that no further extensions of the plant should be necessary for years to come.

All buildings and practically all apparatus now used in generating gas were new within the last ten years and represent in every respect the most up-to-date and modern practice in the United States. It is proper to say that the Providence Gas Works is the model gas plant of New England, if not of the United States.

Coal Gas Works of 1910

The first plant to be erected at Sassafras Point was the Dessau Vertical Coal Gas Works, which was built under the supervision of the Gas Company's Engineer, Mr. Carroll D. Miller, who has described the construction and operation of this plant in papers before the New England Association of Gas Engineers and also the American Gas Institute, from which papers I have liberally drawn for the information given herewith.

Coal Storage Plant

A seawall of stone masonry was constructed and has since been extended to be about 600 feet long, and there is a depth of about

28 feet of water at high tide, which will accommodate all ordinary coal barges and some of the large capacity steamers. For unloading coal from barges and delivering to the storage pile or storage shed, a coal bridge (Figure 2) was erected by the Brown Hoisting Machinery Company. This coal bridge has a capacity of 100 to 150 tons per hour, depending on the conditions. Coal is picked up with a two-ton clamshell bucket. One leg of the coal bridge runs on the seawall, the other leg on rails close to the coal shed, with a

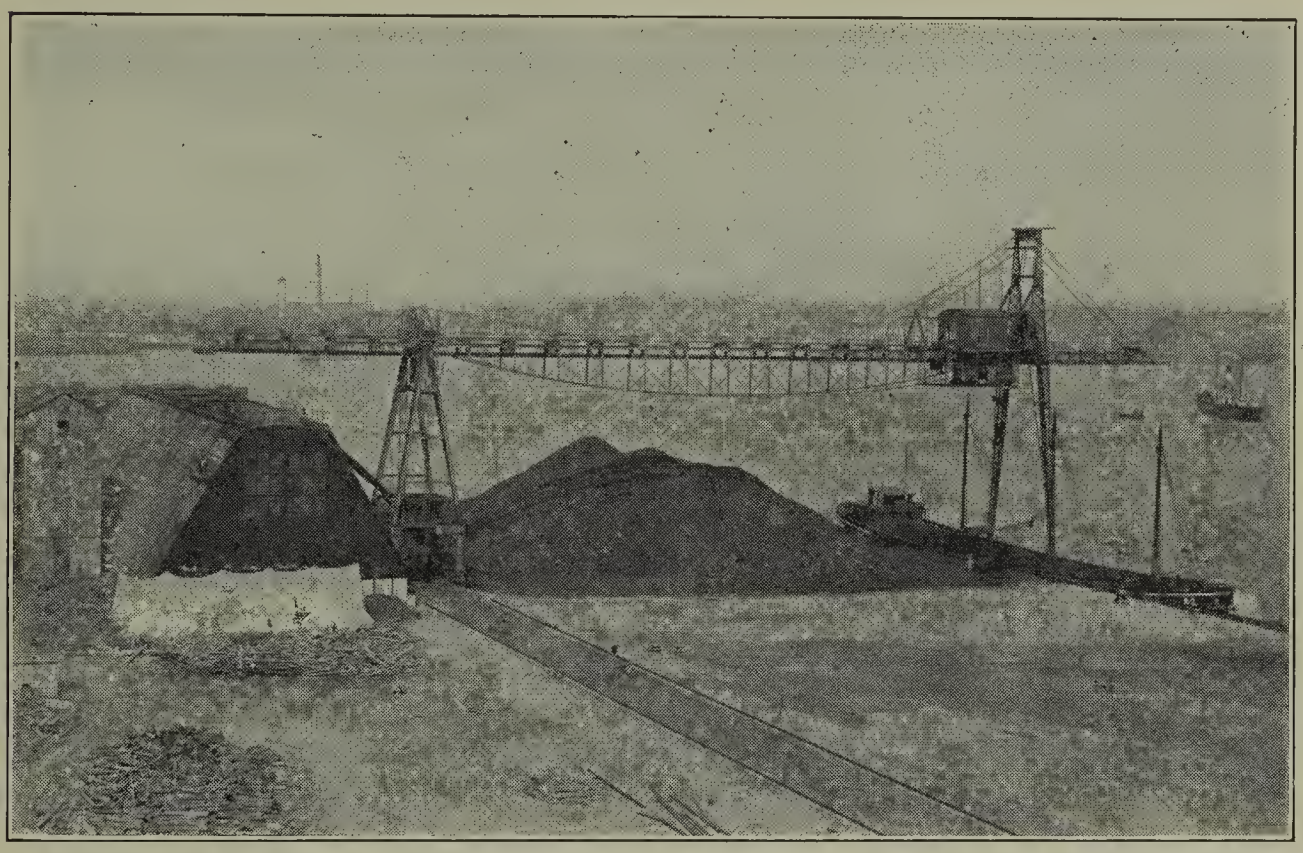

Fig. 2.—Coal Bridge and Coal Storage House.

211-foot span. The trolley handling the clamshell bucket has a travel of 304 feet and the total length of the bridge is 324 feet, including overhang. The clearance of the bucket from the ground is 56 feet.

The bridge can travel in longitudinal direction 600 feet. Coal can be unloaded with this bridge from barges to the storage pile and then rehandled into the shed, or it can be handled by the bridge from barges into the shed, or it can be dropped directly into the hopper feeding the coal crushers and belts to the retort house.

At the north end of the storage ground is an open bin of 1000 tons capacity, which is now being used for buckwheat boiler fuel. Adjacent to this is a space reserved for 10,000 tons of broken

anthracite for water gas generation. The rest of the storage space is divided up between high volatile and low volatile coking coals with storage capacity of a total of about 60,000 tons.

Coal Shed—The coal storage shed was arranged to store a maximum of 8000 tons of coal under cover.

The framework of the shed is constructed of "A" steel frame bents, the bents being designed to carry the sides, roofing and tracks of the main trolley, which is used for reclaiming the coal from the storage shed and passing same into the hopper over the crusher.

The bottom of the coal shed and foundations of the steel frame are of concrete. The roof over the shed is provided with movable sections or hatchways, so that the storage bridge may deposit coal into any portion of the shed. This storage shed was originally used for gas coal for the retort house but is now used for storing bituminous coal for use in the producer gas plant. The reclaiming is done by means of Dodge telphers, having two-cubic yard buckets.

Retort House

The Retort House, which was built entirely by the Didier-March Company, is of German design. (Figure 3.) The building is 85

Fig. 3.—Desson Vertical Retort House.

feet wide, 215 feet long and 59 feet high to the ridge. The roof is open in the center to give the greatest possible ventilation, combined with louvres placed in the side walls of the house. There

were also provided 28 double sliding doors to make the house easily accessible from all sides and 74 windows. A platform was constructed in front of each stack at the height of the bottom of the retorts and another platform in front of the hydraulic mains, with an operating floor around the tops of the benches. The roof was constructed of graduated reinforced asbestos sheets fastened to channel purlins with aluminum wires.

Coal Handling—A steel hopper receives the coal from the telpher or bridge, dropping it into a weighing hopper and from thence the coal goes onto an apron feeder, which carries the coal to jaw crushers. From the jaw crushers, bucket elevators carry the coal to the top of the retort house. These bucket elevators have 66-foot centers and are made up of No. 10 steel "V" shaped buckets measuring 20 inches by 50 inches, driven by motors. The bucket elevators discharge onto belt conveyors having 200-foot centers, which deliver the coal from the elevator to the coal bins. This belt is 18 inches wide and is provided with a self-propelling automatic reversing tripper running on rails, which discharges the coal automatically over the entire length of the coal bin. Each of these coal bins has a capacity of 260 net tons and is constructed of steel plates properly stiffened. Each bin is provided with a series of discharging valves of the swinging undercut type. At the present time, as the retort house has been abandoned for generating coal gas, the north bin is not in use. The south bin is now used for the fuel for the producer gas plant, which furnishes the gas for heating the coke ovens.

Benches—Four stacks of vertical benches were erected, three consisting of six benches of ten retorts each, the fourth consisting of six benches of fifteen retorts each. In the benches of 10's, the retorts measure 22½ inches by 9 inches at the top and 27 inches by 14 inches at the bottom and are 13 feet 2 inches long. The recuperating system is located on both sides of the generators, consisting of a system of primary and secondary air flues and adjacent to a series of waste heat flues which convey the products of combustion to the lower portion of the benches. (Figure 4.)

The generators were located on one side of the benches adjacent to the retorts and the producer gas entered the main oxide flue through two openings about 3 feet above the grate bars. The coke charging openings are located some 14 feet above this point on

a level with the retort operating floor, this space serving for coke storage.

A vaporizer for each generator was located underneath the ash pan and vaporization was effected by the products of combustion before entering the main smoke flue. The vapors produced were conducted under the grate and thoroughly mixed with the heated primary air. A separate main smoke flue 3 feet square was provided for each stack connected to the chimney outside the building. Four chimneys were erected of hollow radial molded blocks of the

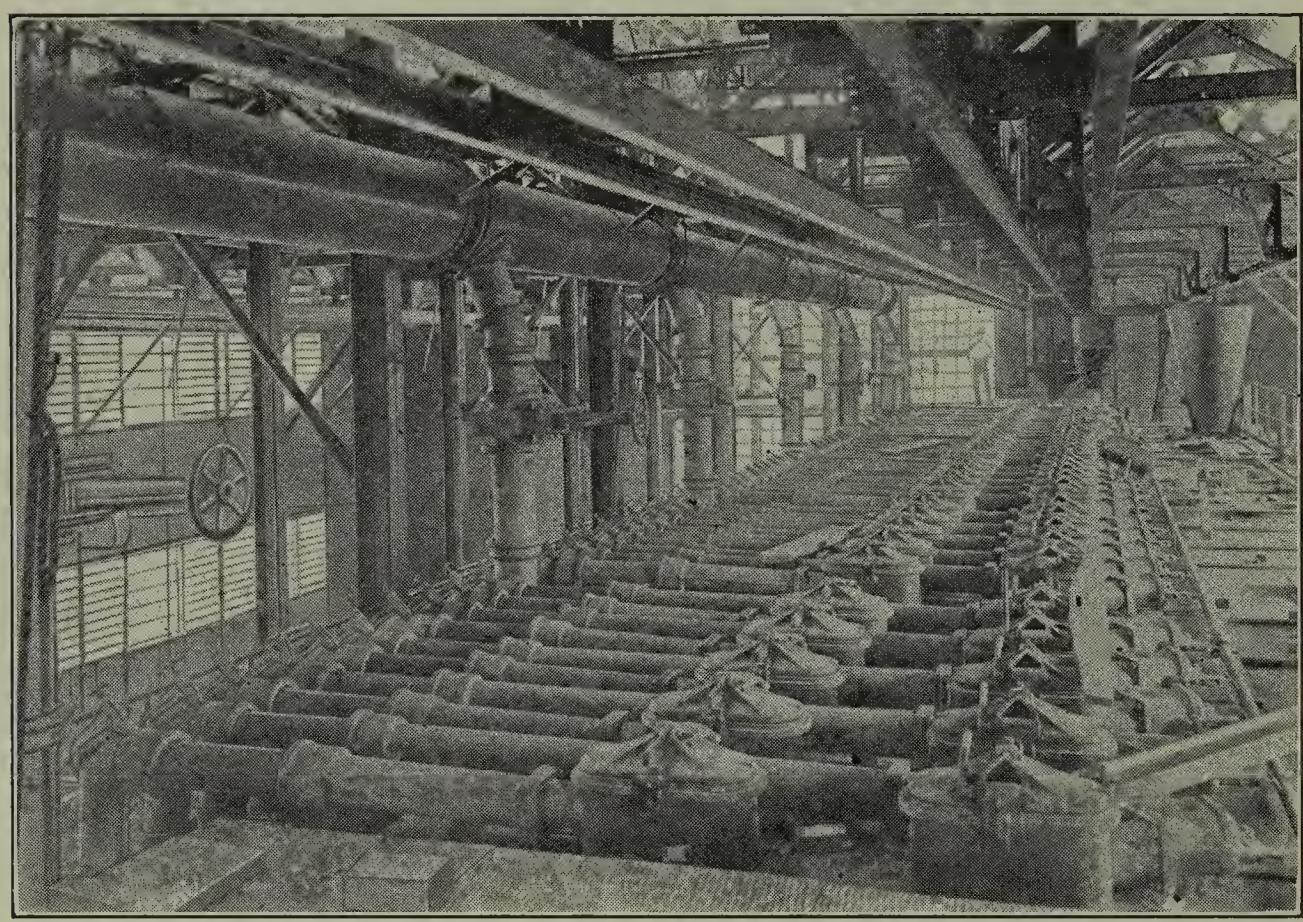

Fig. 4.—Top of Benches.

Custodis system and are 125 feet high with 4 feet inside diameter at the top.

The lower mouthpieces were operated from the outside of the benches by means of a system of levers, racks and pinions. A separate hydraulic main was provided for each bench. These hydraulic mains were only sealed during charging of the retort, which was accomplished by means of a weir valve, which was raised shortly before charging time and which allowed the circulating liquor to fill up and seal the dip pipes. Underneath each dip pipe was placed a pitch pan, which could easily be removed for cleaning.

Two foul mains, one on each side of the house, carried gas to the end of the building and thence to the underground foul main.

For charging the generators with coke, a steel plate hopper was used, running on a mono-rail. Before charging coal into the retort, the bottom of the retort was filled with a small amount of coke breeze by means of a traveling breeze hopper. This was followed by the coal charging hopper, which was constructed to charge two retorts simultaneously on the benches having ten retorts and

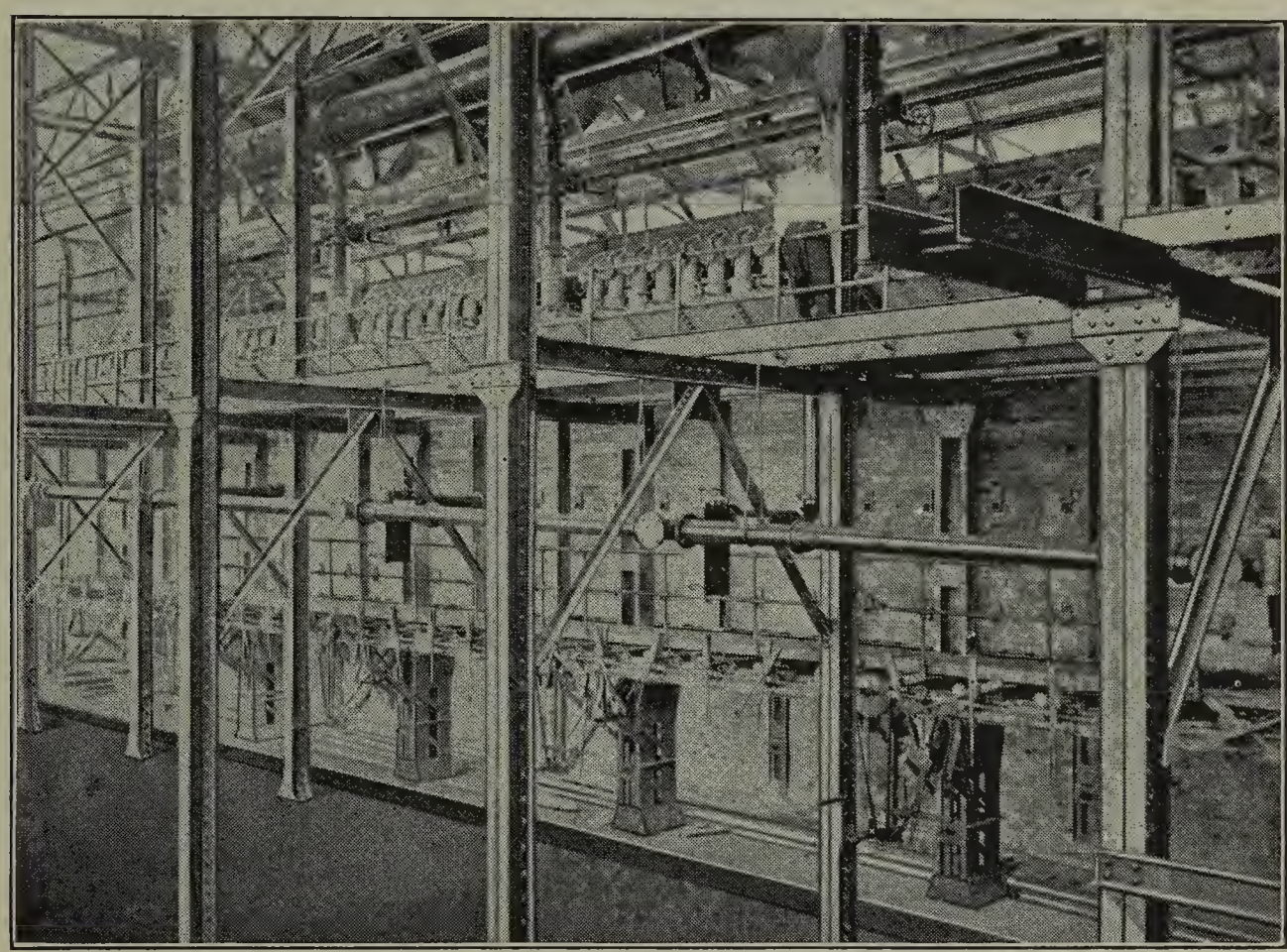

Fig. 5.—Side View of Benches.

three retorts on the benches having fifteen. The coke which discharged from the retorts fell into a movable chute, which brought the coke over to a DeBrower hot coke conveyor located in front of the stacks. (Figure 5.) Originally the conveyor discharged into a skip hoist, which elevated the coke into a night storage bin, but this system was found unsatisfactory and was changed to deliver the coke into a second conveyor, which, in turn, carried the coke to concrete pits. Just outside of the retort house was a set of water sprinklers, which quenched the hot coke, the steam being carried away by a vertical flue.

The fourth stack of benches to be erected was built with fifteen retorts to the bench, which was thought to give some economies in operation. The retorts were 19⅝ inches by 9¾ inches at the top and 24⅜ inches by 14⅛ inches at the bottom, having the same length of 13 feet 2 inches. The other constructional details were similar with the exception of the method of handling the lower mouthpieces, which were handled by hydraulic valves rather than by hand, which was an immense improvement. Also the steam vaporizers were omitted and step grates were used instead of bar grates. Step grates were also used on the third stack to be built.

The coke which was quenched by the water sprays and carried by a second chain conveyor passed over a grizzly, where a large part of the breeze dropped out, and then fell into concrete pits, from whence it was handled by telphers.

A telpher system with a clearance of 54 feet above ground level handled the coke from the pits to storage or to the screen houses. These telphers were later extended to handle coke to the water gas plant and also anthracite for the water gas plant and coke breeze or other fuel for the boiler plant and, at the time of completing the coke oven plant, they were still further extended to take care of the coke from the ovens.

The coke was handled to storage and to the shaker houses with 2½-ton clamshell buckets.

Condensing Plant

Buildings—At the time this plant was built, it was common practice to house all condensing plants. In the past few years, the use of outdoor condensing plants has grown rapidly in favor. The condenser house (Figure 6) is 45 feet wide by 120 feet long and about 30 feet high, with brick walls carrying steel roof trusses. The roof is of terra cotta book tile covered with slate with a monitor extending the whole length of the building, having pivoted sash. Concrete floors are provided throughout.

Condensing Equipment—The condensing plant as originally constructed consisted of two primary condensers, two exhausters, two tar extractors, two secondary condensers, two rotary ammonia scrubbers. Later a Feld washer was constructed to assist in ammonia recovery.

Primary condensers are rectangular water tube condensers, having 3200 cubic feet effective cooling surface each. The combined capacity of these two condensers is 3,000,000 cubic feet per day.

Following the primary condensers is a duplicate installation of Connersville exhausters, having a capacity of 17 cubic feet per revolution, and equipped with Isbel-Porter governors. Tar extraction is provided for by two Bartlett-Hayward P. & A. tar extractors with a single submersion chamber, the shell being of cast iron.

Fig. 6.—Water Tank, Purifier House and Condenser House.

There are two of these tar extractors and each of them has a capacity of 3,000,000 cubic feet per day.

Following the tar extractors are two secondary rectangular water tube condensers, each having an effective surface of 6,000 square feet. (Figure 7.) The water used on the secondary condensers passes to the primary condensers. The temperature of condensation is controlled by Tagliabue regulators.

A 5-foot, 7-section Feld washer serves as a primary ammonia scrubber and has developed into a very useful apparatus, for the

removal of hydrogen sulphide, in combination with ammonia in the liquor from the secondary scrubbers.

The final removal of ammonia was secured by two rotary scrubbers (Figure 8) constructed in five bays, having a diameter of 10 feet. The washing surface is composed of standard wood grids, the washer being supplied with a small engine directly connected to a worm operating on the worm wheel attached to the

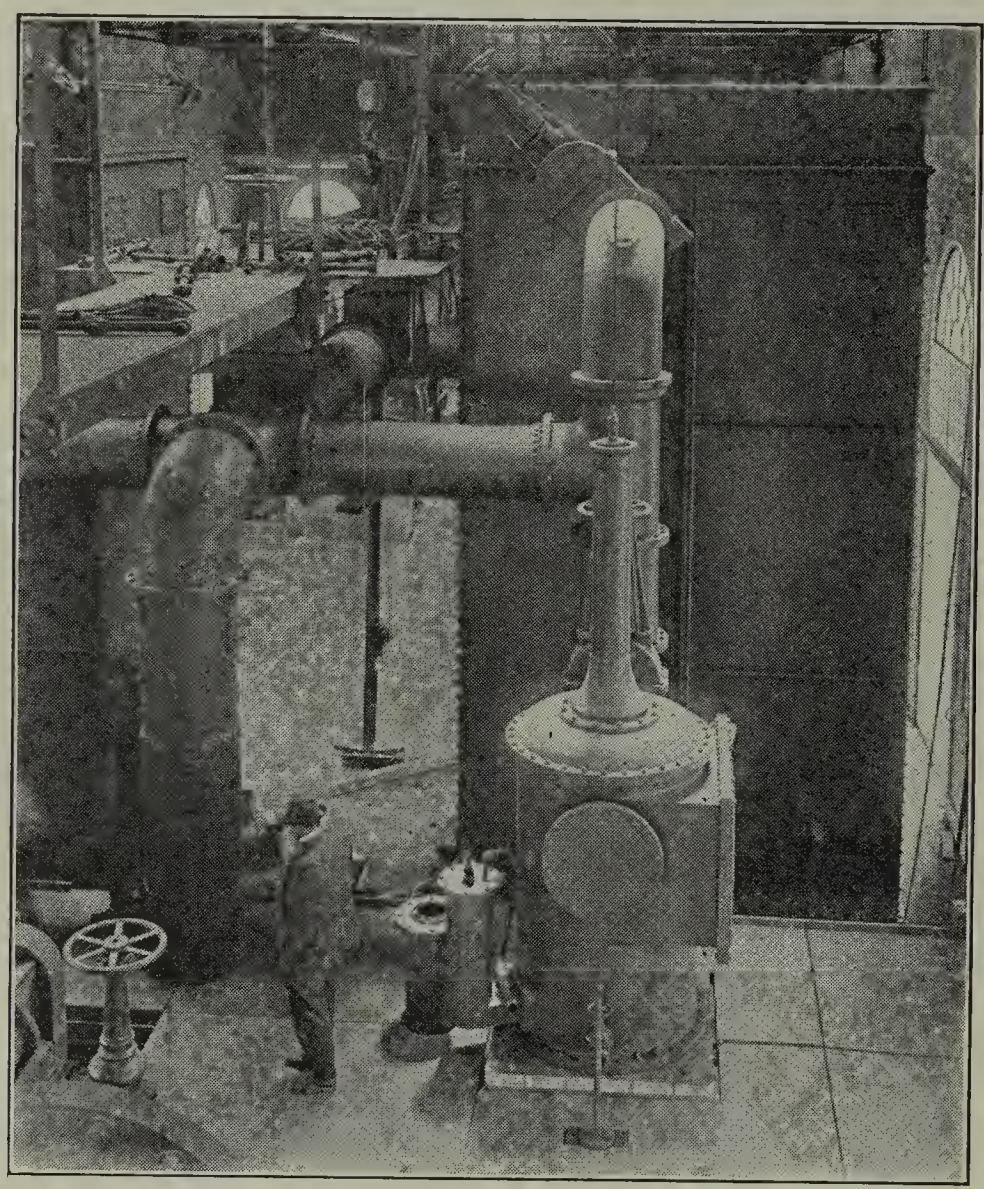

Fig. 7.—Secondary Condensers.

shaft. All connections in the building are 24 inches diameter, straight pipe made of steel plates, all fittings being made of cast iron.

The tar and liquor from the retort house run into an underground concrete system 20 feet by 45 feet by 10 feet in depth, where the tar and liquor condensed in the retort house are separated. The weak liquor collected at this point was used for sealing

the hydraulic mains and finally found its way to the main ammonia liquor storage. The tar collected in the separator was pumped to an overground steel tank located near the retort house.

Alongside the condenser house, there is an underground concrete ammonia tank measuring 35 feet by 120 feet by 10 feet in depth, wherein is received and stored all the tar and liquor collected from the condensing and purifying plants. The tar separated

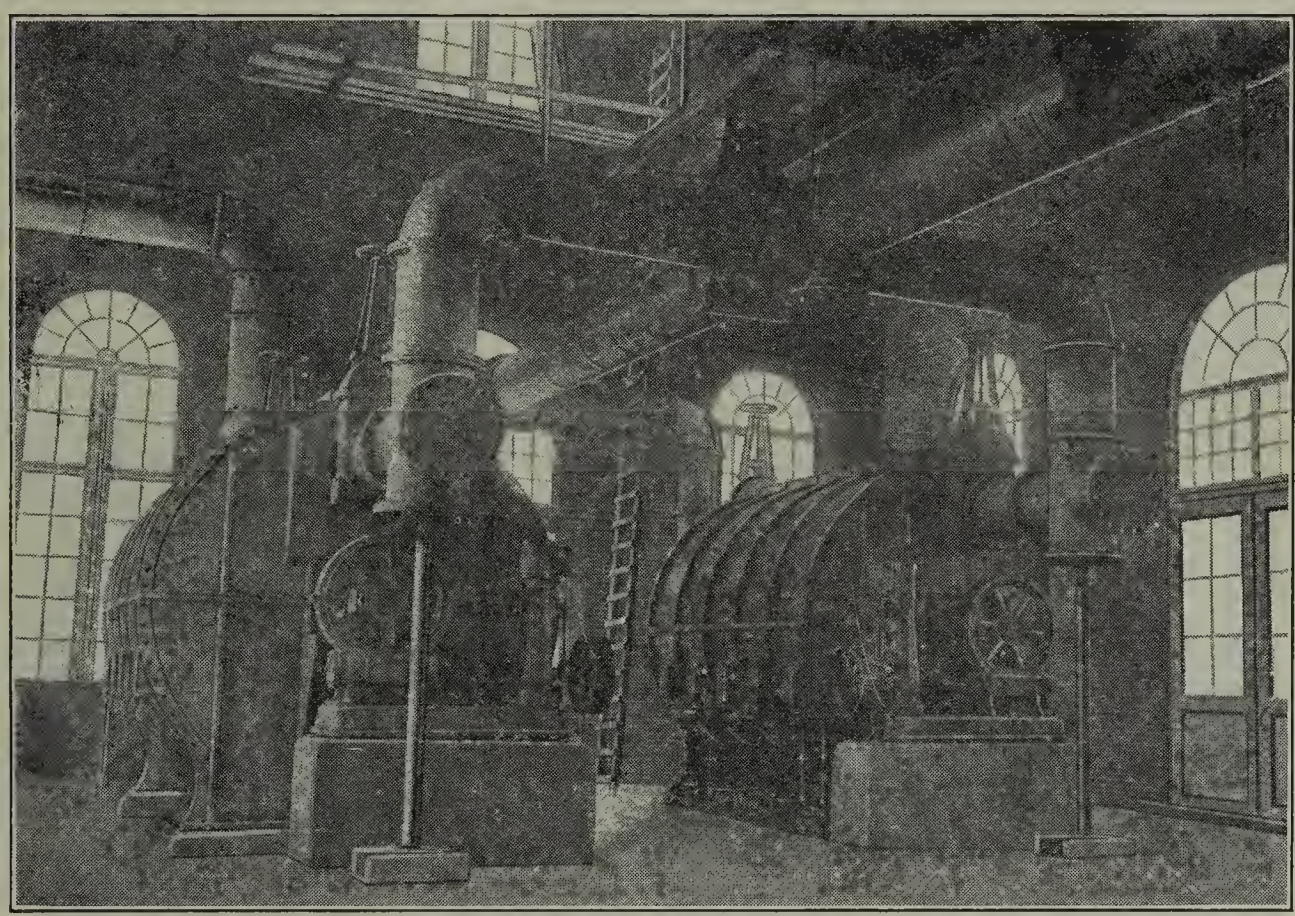

Fig. 8.—Rotary Scrubbers for Final Removal of Ammonia.

at this point was sent to the overground tar tank and the ammonia delivered to the ammonia works.

Purifying Plant

Buildings—The purifier house (Figure 6) is 110 feet long by 61 feet wide and 36 feet high and accommodates four purifiers. The building is of steel frame, the space between the frames and around the outside of the columns being built of brick. The roof is covered with book tile carrying slate. A stairway leads from the ground floor to the operating floor around the boxes. This operating floor is built of steel plate. The roof is provided with a monitor

extending the whole length of the building carrying a monitor sash. The general design of the building is similar to that of the other plant buildings, having granite trim and general handsome appearance. The purifying boxes measure 40 feet by 20 feet by 10 feet deep and contain three layers of oxide with valve connections to provide a triplex flow of gas. (Figure 9.)

The covers of the boxes are supplied with rubber lutes and holding down clamps and are handled with an overhead traveling

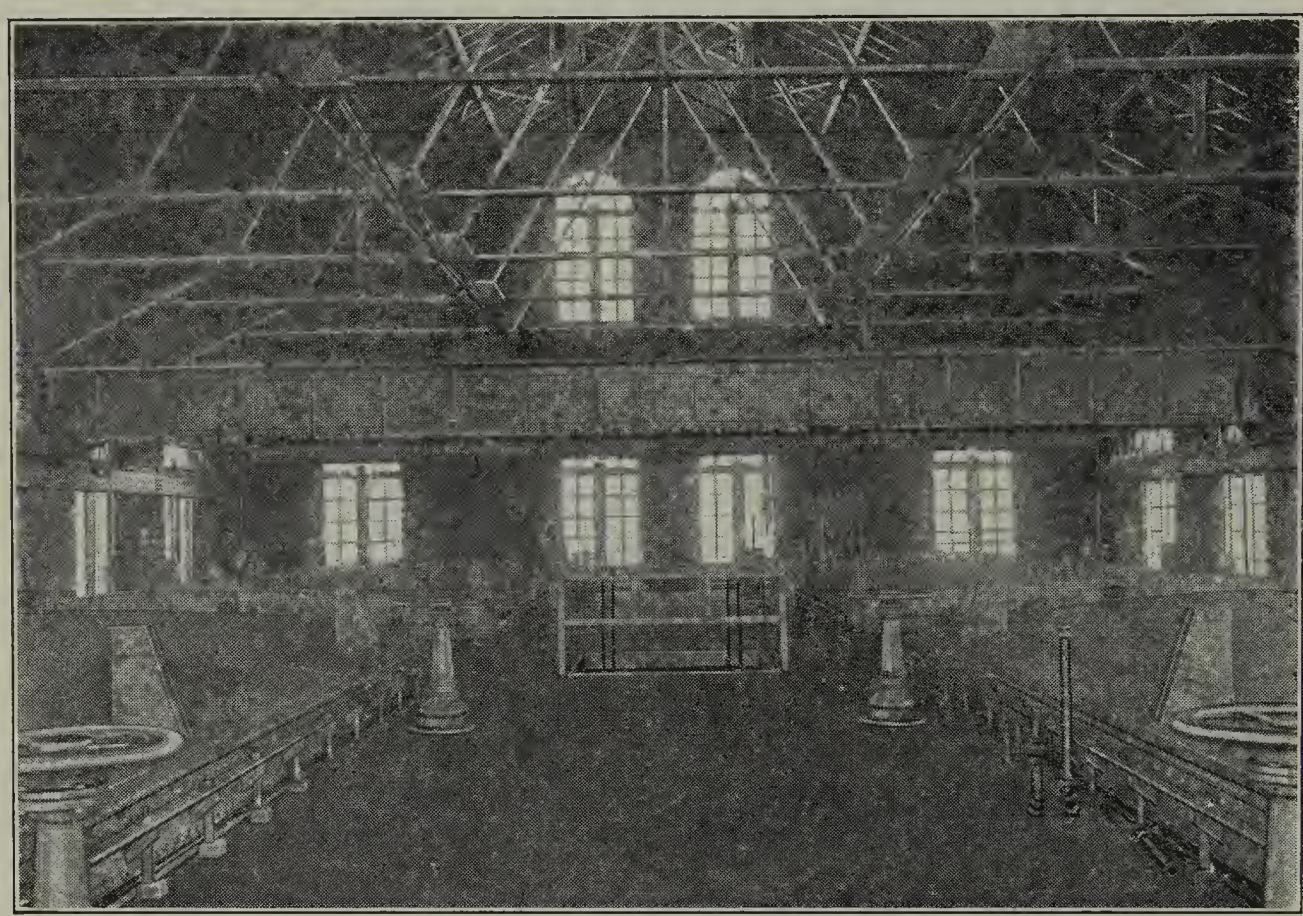

Fig. 9.—Coal Gas Purifier Boxes.

crane. The system of valves and fittings are arranged so as to work the boxes either in forward or backward rotation.

In dumping a box, the oxide is dropped through openings in the bottom of the box onto a concrete floor. In filling a box, the wheelbarrows of oxide are raised to the operating floor by a Craig Ridgway steam hydraulic elevator.

Meter House

From the purifying plant, the gas passes underground in a 24-inch main to the meter house, which is 40 feet by 45 feet by 20

feet, constructed of brick with steel roof trusses, the roof being of book tile carrying slate. Space is provided in this building for four meters. When the coal gas plant was built, one 14-foot meter was installed by the Nathaniel Tufts Meter Company and supplied with a Hinman drum. A photometer room was also constructed in the space provided for one of the future meters.

Power Plant

The power plant is housed in two buildings: one containing the boilers and the other containing the engines, generators and auxiliary machinery. The boiler house is 88 feet by 65 feet by 30 feet high, of the same general construction as the other buildings on the plant. When first built three B. & W. 440 H.P. boilers were installed, equipped for hand firing. A radial brick chimney was provided and additional forced draft was secured by means of an engine driven Sturtevant fan. An open feed water heater was provided for the boiler water but for the first few years, very little exhaust steam was secured and the temperature of the water entering the boilers was never very high.

Engine House—The engine house is 46 feet by 90 feet and contains a main operating floor and basement. On the main operating floor are two 300 K.W. cross compound, direct connected Allis Chalmers engines and generator. (Figure 10.) These engines run condensing, utilizing salt water from the Bay to operate barometric condensers. 250-volt, D.C. electric current is generated and is distributed through a switchboard to various circuits in the plant. Electric power is utilized for all possible operation of machinery.

In the cellar of the engine house are located the centrifugal boiler pumps, the condensing pumps and the fire pump, which utilizes salt water from the Bay.

Water Tower and Wells—There are three sources of water supply for the Works. Water from the city mains is used for boilers and other purposes where pure, fresh water is required. A set of driven wells were put down to a depth of about 50 feet, tapping underground veins of water, which sometime after their construction unfortunately became contaminated with salt water from the Bay. These wells are provided with two Davidson electric pumps, delivering the water into a tank on a tower, the tank

having a capacity of 100,000 gallons of water and being elevated about 80 feet from the ground.

Results in Operation

The coke made in this plant was of a very superior quality and found a ready sale for all domestic purposes. The yield of gas, tar and ammonia were satisfactory. When the plant was first started, it was very economical as to labor but conditions later developed which caused the labor account to be high.

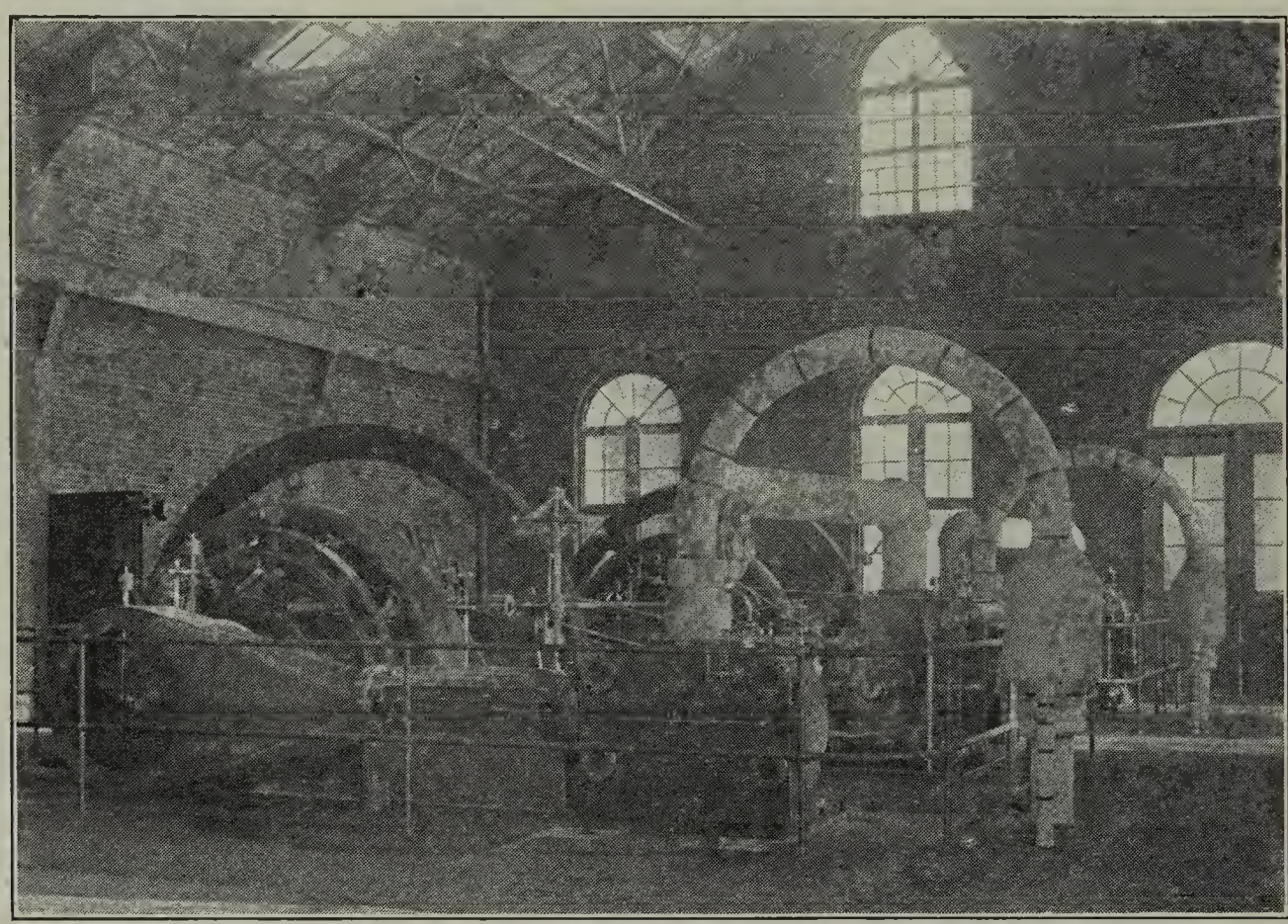

Fig. 10.—Engine Room.

This was the pioneer plant in America of Dessau vertical retorts, which accounts for many of the operating difficulties encountered. There are now several very successful installations of vertical retorts on the Dessau system wherein American conditions have been more thoroughly taken into account.

Water Gas Plant

During the year 1915, it became evident that the capacity of the South Station for generating water gas would soon be exceeded by

the demand, and it was decided to build a complete new water gas plant at the Sassafras Point Station. In July, 1915, The Bartlett-Hayward Company of Baltimore, presented plans and specifications for this plant, which were accepted and construction was commenced, gas being made in the new plant about the first of December, 1916. Mr. R. E. Slade had succeeded Mr. Carroll Miller as Engineer for the Gas Company, and it was under his direction and supervision that the water gas plant was planned and constructed. The manufacture of water gas at the Sassafras Point Station involved the erection of a number of buildings, including a generator house, engine house, washer house, purifier house and a set of coal and coke bins. It also involved the erection of a relief holder, two oil tanks, extension of the boiler capacity, extension of telpher lines, the moving of two station meters from the South Station to the new plant and also a 500,000-gallon tar tank. (Figure 11.)

With the exception of the water gas machines, which were furnished and installed by the United Gas Improvement Company, all of the construction was undertaken by The Bartlett-Hayward Company, although apparatus from several other firms was specified for certain purposes.

Coal and Coke Handling

Adjoining the generator house and located between the generator house and the boiler house, a set of coal, coke and breeze bins were erected. These bins were about 120 feet long and 23 feet wide and were constructed of steel plates stiffencd with steel beams supported on "H" columns roofed over with asbestos protected metal. A steel partition runs lengthwise through the bunkers, so that boiler fuel may be separated from water gas fuel. In addition to this, wooden partitions were later put in, so that water gas coal and water gas coke could be separated and also different varieties of boiler fuel could be kept separate.

There are steel chutes with undercut gates serving the boiler house and the operating floor of the water gas plant.

Anthracite which is stored on the waterfront is delivered into the north end of the coal storage shed by the coal bridge. The telpher lines were extended to serve this coal store and coal is brought by telphers to a new hopper, which also takes coke, breeze

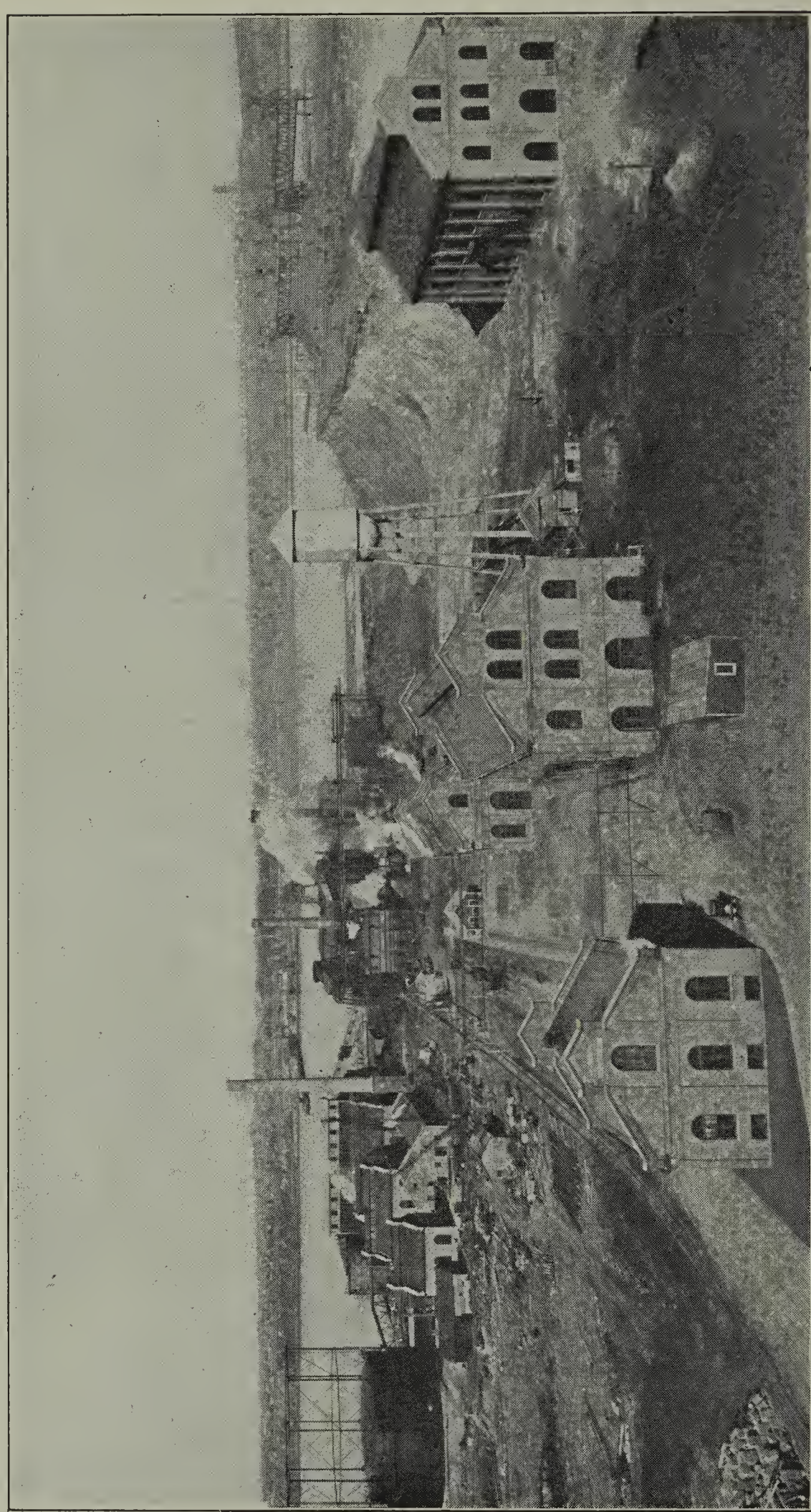

FIG. 11.—General View showing Original Coal Gas Plant and Water Gas Plant built in 1915.

and boiler coal handled by telphers from their respective storage piles. This hopper delivers to a motor driven 30-inch belt, having 205-foot centers, with a capacity of forty tons per hour, which conveys the fuel up an incline to the proper elevation, thence horizontally above the bins to the end of the bin house. A traveling unloader runs on rails above the bins and discharges the fuel where desired.

Buildings

The generator house is of steel frame construction, the roof being carried on steel purlins and trusses, the trusses spanning the

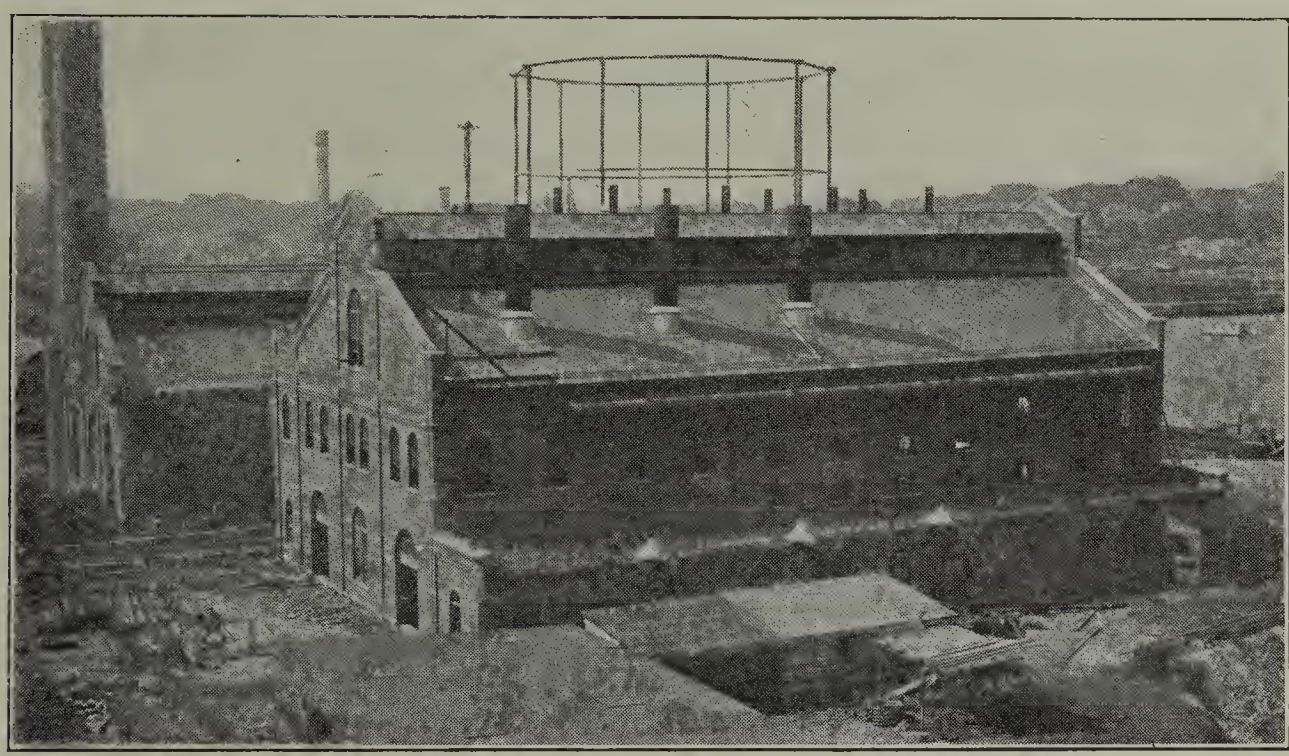

Fig. 12.—Generator House.

entire width and being supported on steel columns securely anchored to the building foundations, so that all loads are carried independent of brick side walls. A steel frame monitor, carrying swinging windows, is constructed on the roof. The end walls are carried up above the ends of the roof and are capped with stone. This building is 217 feet long, 71 feet wide and 31 feet 10 inches high from the ground floor to the bottom chord of roof trusses. This building was so laid out as to accommodate five sets of water gas generating apparatus, but to date three sets only have been installed. (Figure 12.)

The exhauster and pump house is 60 feet long by 41 feet wide and is of the same general construction as the generator house. The operating floor for the engines and exhausters is slightly above grade, and a pump room is provided somewhat below grade. Space was provided for three exhausters, only two being installed at present.

The tar extractor and washer house is 41 feet long, 37 feet wide and 21 feet high. It has 13-inch brick walls with stone trim, the roof being carried on steel trusses anchored to 17-inch pilasters. There is a monitor on the roof with pivoted sash.

The purifier house is of steel frame construction with brick filled sides and gable roof, the roof being carried by steel purlins and supported by trusses carried on steel columns. An outside steel stairway runs to the purifier floor. There is an additional stairway inside the building. The dimensions are 112 feet by 61 feet inside and 44 feet 6 inches high from the ground floor to underside of roof trusses.

The roofs of all buildings are of terra cotta book tile laid in cement with slate covering. All buildings are substantially built and have a handsome appearance.

Water Gas Machines

Three 11-foot 6-inch U.G.1 standard carbureted water gas machines were installed. (Figure 13.) Air for blasting is provided individually for each machine, but by means of a manifold any one of the three blowers may serve the machines. In routine operation, one blower serves one machine only. The blowers were furnished by the Rateau-Battu-Smoot Company and consist of standard Rateau steam turbines, each driving two bi-rotor blowers, there being two impellers within a single casing acting in parallel, the inlet and discharge connections being connected in parallel with a single orifice in each case. The radial impeller blades are dovetailed into a heavy steel shaft. Volutes feed suction air to the impellers and after leaving the impellers, the air enters the diffusion chamber, wherein discharge velocity is converted into pressure. The blower casing is parted on the horizontal center line, inlet and outlet nozzles being located in the lower half. These blowers operate at comparatively high speed—about 7,500 revolutions per minute—and, as the blower shaft is so designed as not to pass

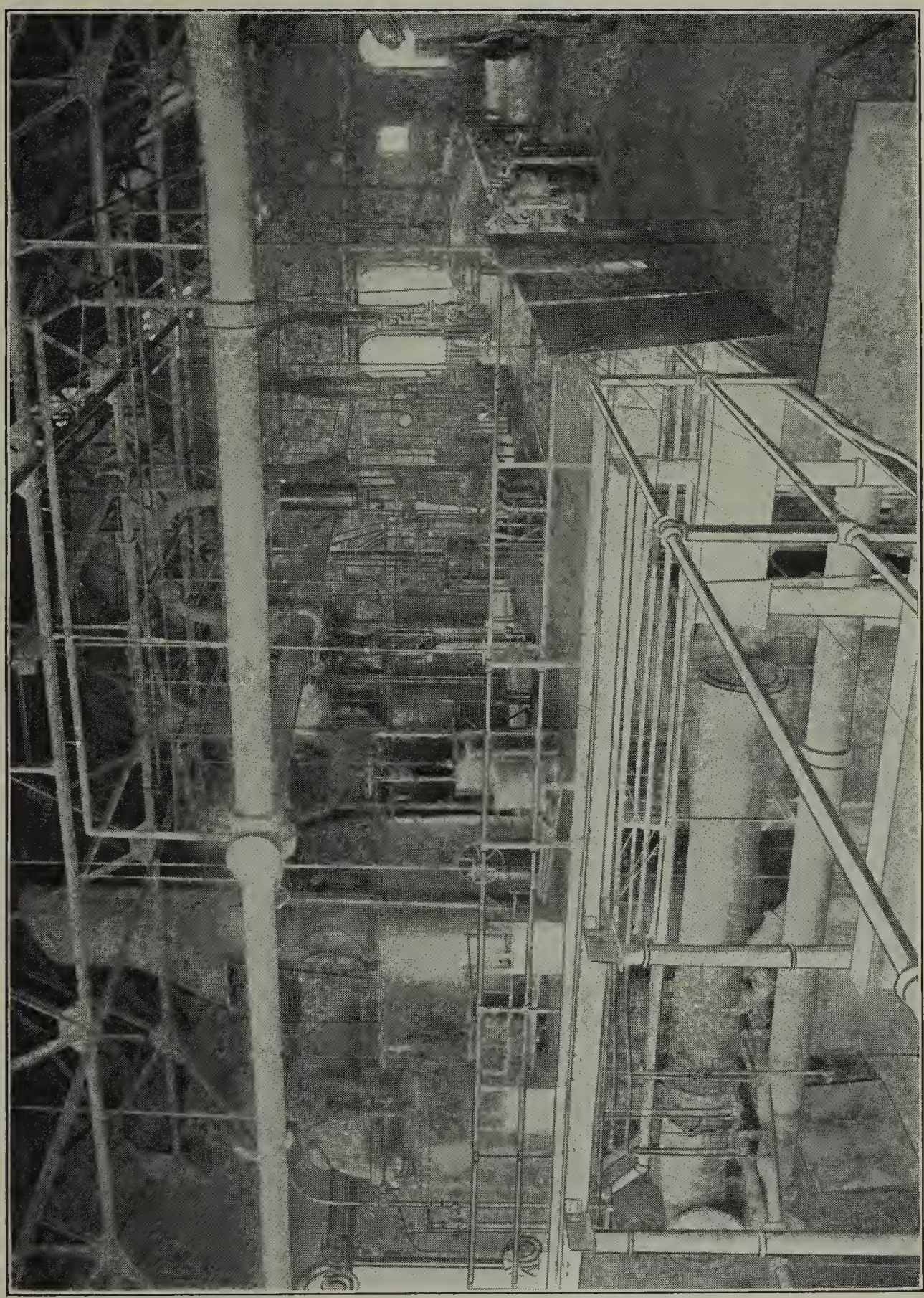

FIG. 13.—Generator House. Operating Floor.

through its critical speed, the blowers may be stopped and started at frequent intervals, it being possible to bring them from rest to full speed in ten seconds after having been heated up. On account of the high speed, great care had to be taken in designing the lubrication. The bearings are amply large and are provided with oil rings and water cooled chambers.

The steam expands in the stationary nozzles and drives the rotary element on a single row of buckets. The pressure of air is maintained by means of a constant pressure regulator, which acts directly on the steam, being adjusted for any given air pressure by a weight sliding on a lever arm. These turbo blowers have been highly satisfactory. At 140 pounds steam pressure, they have delivered 20,000 cubic feet of air per minute through a 20-inch pipe with 36 inches pressure at the Venturi meter. It is necessary to give such apparatus more care than is usually given to blast equipment for water gas sets.

The stack valve, up and down run valve, steam valve, secondary and primary blast gates are all handled by hydraulic valves. These hydraulic valves are controlled by a group of levers set together at a convenient place for the operator of the machine. The action of these valves is extremely smooth and satisfactory and has made the labor of operating the machines very light compared to the old-fashioned manner of working.

During the period of blowing, the amount of secondary air required to make perfect combustion at the stock must constantly be increased and to maintain this condition, an automatic device is made use of. This device consists of a small gas holder, which is filled during the blow by the air pressure from the main blast line. As this little holder gradually rises, it automatically increases the flow of air to the carburetor and, by means of simple adjustments, the right amount of air is admitted during each minute of the run to secure complete combustion of the carbon monoxide generated.

Venturi meters are used for measuring the flow of air to the generators during the blow. The pressure indication of the Venturi meters is transmitted to a water column placed on the gauge board of the machine, this water column having a graduated scale, from which may be read off the amount of air in cubic feet passing the fire per minute.

Venturi meters are also used for measuring the up-steam and down-steam used during the gas making period. The meters are

equipped with indicating dials, which show directly the number of pounds of steam entering the fire per minute of run.

To indicate the temperature at the top and bottom of the superheater, Bristol indicating pyrometers were originally installed. During the last year, on account of the poor oil and fuel which were obtainable, much more careful operation of the machines was demanded and Thwing recording pyrometers were installed, which make a record of the temperature at three points, namely: the middle of the carburetor and top and bottom of the superheater. These instruments are installed in a little dust-proof room just off the operating floor and have given great satisfaction.

A gaugeboard is provided for the use of the operator of the machines, located in a convenient place for his observation. On this board are placed gauges showing the pressure of the blast air and, during the run, of the pressure under the grate and the pressure leaving the machine. On the upper part of the gaugeboard is a gas maker's clock with a very conspicuous second hand, two dials, indicating, respectively, the amount of steam used on up-runs and down-runs, and a graduated gauge glass for indicating the amount of air passing through the generator during the blow and a gauge indicating the pressure of oil in the line going to the sprays. Back of this gaugeboard and in a convenient location is the battery of levers which control the operation of the hydraulic valves used in handling the various parts of the machine. There is also a meter for measuring the amount of oil admitted to the machine during each run. On the wall directly back of this bank of valves is an indicating pyrometer. It will be seen that great care has been taken to make the work of the operator convenient and easy, and it is possible to secure a very high degree of efficiency by such an arrangement.

The general design of these water gas machines does not depart from the standard American Lowe carbureted water gas plant as developed by the United Gas Improvement Company and embodies those details of construction and operation which have proven themselves by many years of successful operation.

Coal or coke for use in the generators is delivered by means of chutes from the outside bins to trucks or buggies on the operating floor. These buggies hold about 3,600 pounds of coal and are drawn over scales for weighing before discharging their contents into the generators.

Washer Tar Batter

This apparatus is a somewhat recent development of the United Gas Improvement Company and it takes the place of the seal pot and tray scrubbers usually employed. It is set upon the operating floor at the side of the extended superheater with a short connection from it and consists of a steel plate shell with an internal divided flow dip pipe. Water, tar and foreign matter are removed by impingement on baffles as the gas passes through. In addition to its scrubbing action, the back pressure, during the gas making period, is less with this type of apparatus, owing to the greatly increased perimeter of the 4-way pipe over that of a single dip pipe. This apparatus has given no trouble and has been uniformly successful in its operation.

Gas Main and Relief Holder—Leaving the seal pots, the gas enters a 36-inch outside overhead main, which carries the gas to the relief holder. This main is made of riveted steel pipe and is supported on steel trusses. The relief holder is of 500,000 cubic feet capacity, in two lifts, in a steel tank, and is of the Bartlett-Hayward standard style of construction.

Condensers—Gas is drawn by means of exhausters from the relief holder through a battery of two outdoor water tube condensers. These condensers are rectangular in form and have seven compartments, gas passing from one compartment to the next and being made to impinge upon the tubes by means of baffle plates. These condensers are constructed of cast iron which permits the use of salt water from the Bay. The temperature of the gas leaving the condensers is regulated by means of a Tagliabue control apparatus acting on the main water lines. Two pumps are provided for handling the salt water to the condensers, one of which is a spare. Both are centrifugal pumps, one being motor driven and the other operated by a steam turbine. From each compartment of the condensers a tar drain connects to a common tar main, which delivers tar and condensed water to the general drip system of the water gas plant.

Exhausters and Pumps—Two No. 10 Roots gas exhausters were brought from the South Station and set up in the new engine room. These exhausters have been driven at the rate of 400,000 cubic feet of gas per hour each, which is equal to the largest demand which has yet been placed upon the plant. During the

past year, considerable trouble was experienced with the engines, owing to there being a rigid coupling between the exhauster and the engine and this rigid coupling was replaced by rope couplings, which have given great satisfaction.

In the pump pit in the north end of the engine room are located seven Simplex pumps, which serve the general yard drips, circulating water to the submersion washer, washer tar batters, tar tanks and oil supply from the oil tanks to the water gas machines.

Each pump is equipped with a constant pressure regulator and the oil pumps have, in addition, a by-pass relief valve, so that a very uniform pressure is maintained in the oil line.

Tar Extractor and Submersion Washer—After leaving the exhausters, the gas passes underground to the P. & A. house, where it first enters a submersion washer supplied by the Western Gas Construction Company. This washer operates at a differential of about 2½ inches at full load and is fed with a small stream of warm water from the tar separators. This washer is built in two sections, one above the other. (Figure 14.)

Following the submersion washer is a P. & A. tar extractor, designed and built particularly for water gas tar extraction by the Gas Machinery Company, Cleveland, Ohio. This extractor consists of a steel plate shell, housing a series of concentric slotted metal drums. This extractor operates at a differential of about 7 inches under full load. The capacity of the tar extractor plant is in the neighborhood of 10,000,000 cubic feet per day and the plant has been satisfactory in every respect.

Purifiers—From the tar extraction apparatus, a 30-inch underground cast iron main runs to the purifying house—a distance of approximately 700 feet. There are four purifiers, 45 feet by 25 feet by 12 feet deep. (Figure 15.) The four boxes are set in a line, connected on the long sides by means of common partitions. The sides and bottoms of the boxes are constructed entirely of steel with riveted joints. The inlet and outlet connections are 24 inches in diameter. Each box is provided with two layers of tray supporting beams and two layers of oxide have been used, although provision was made for four tiers, if desired. The valve connections are so designed as to permit of passing the gas through the oxide from top to bottom or from bottom to top and also the boxes may be operated in forward or backward rotation.

To the bottom of each purifier are attached six oxide dumps,

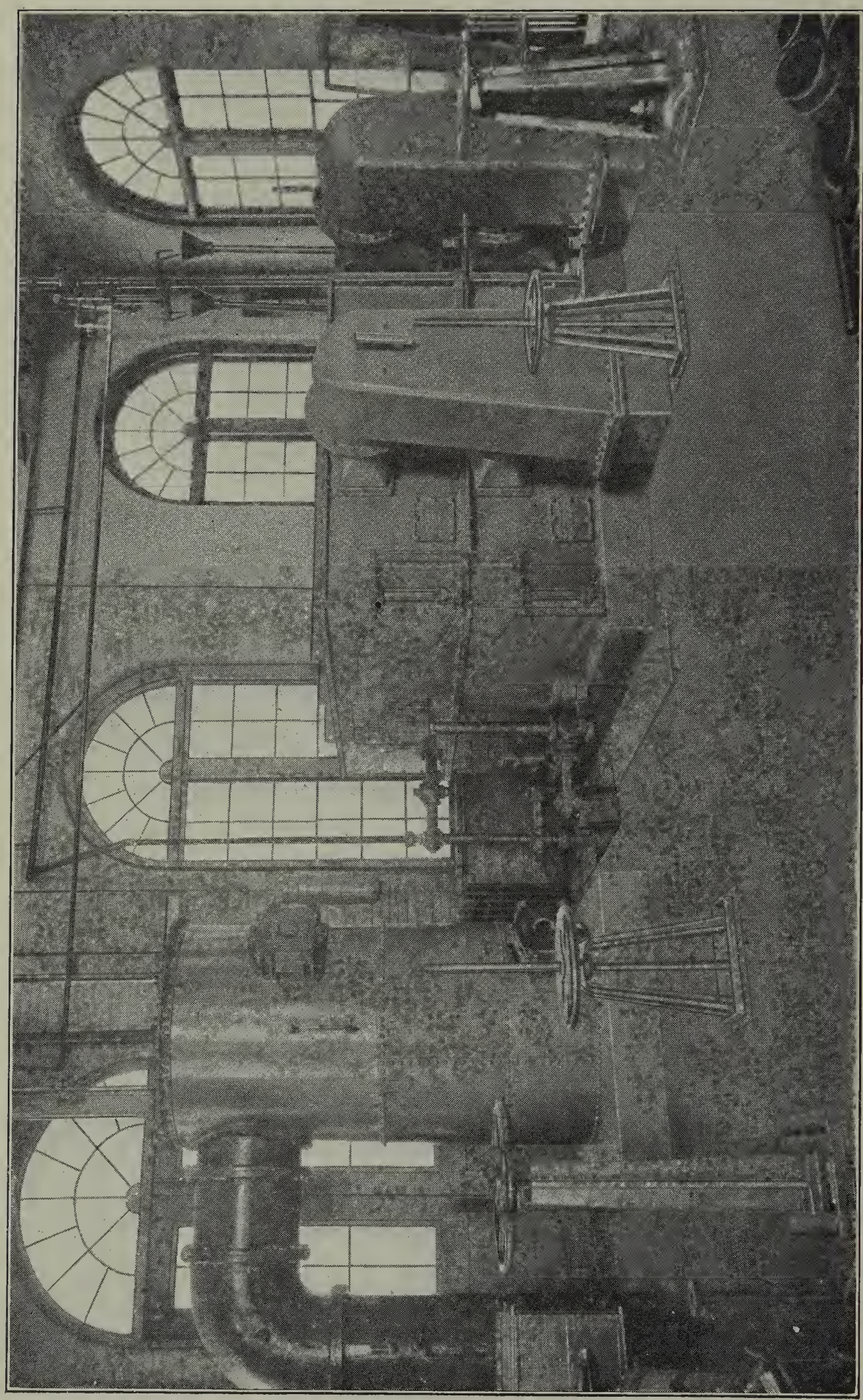

Fig. 14.—Tar Extractor and Washer.

20 inches in diameter, provided with self-sealing lids. The covers are of steel and are trunk shaped, reinforced by means of steel lattice girders located on the inside of the covers. The sides of the covers are formed of a heavy curved angle, which engages with an asbestos lute carried on the frame of the box. The covers are provided with holding-down clamps spaced about 40 inches, center to center, designed to withstand a pressure of 36 inches of gas and any additional load due to tightness of the clamps.

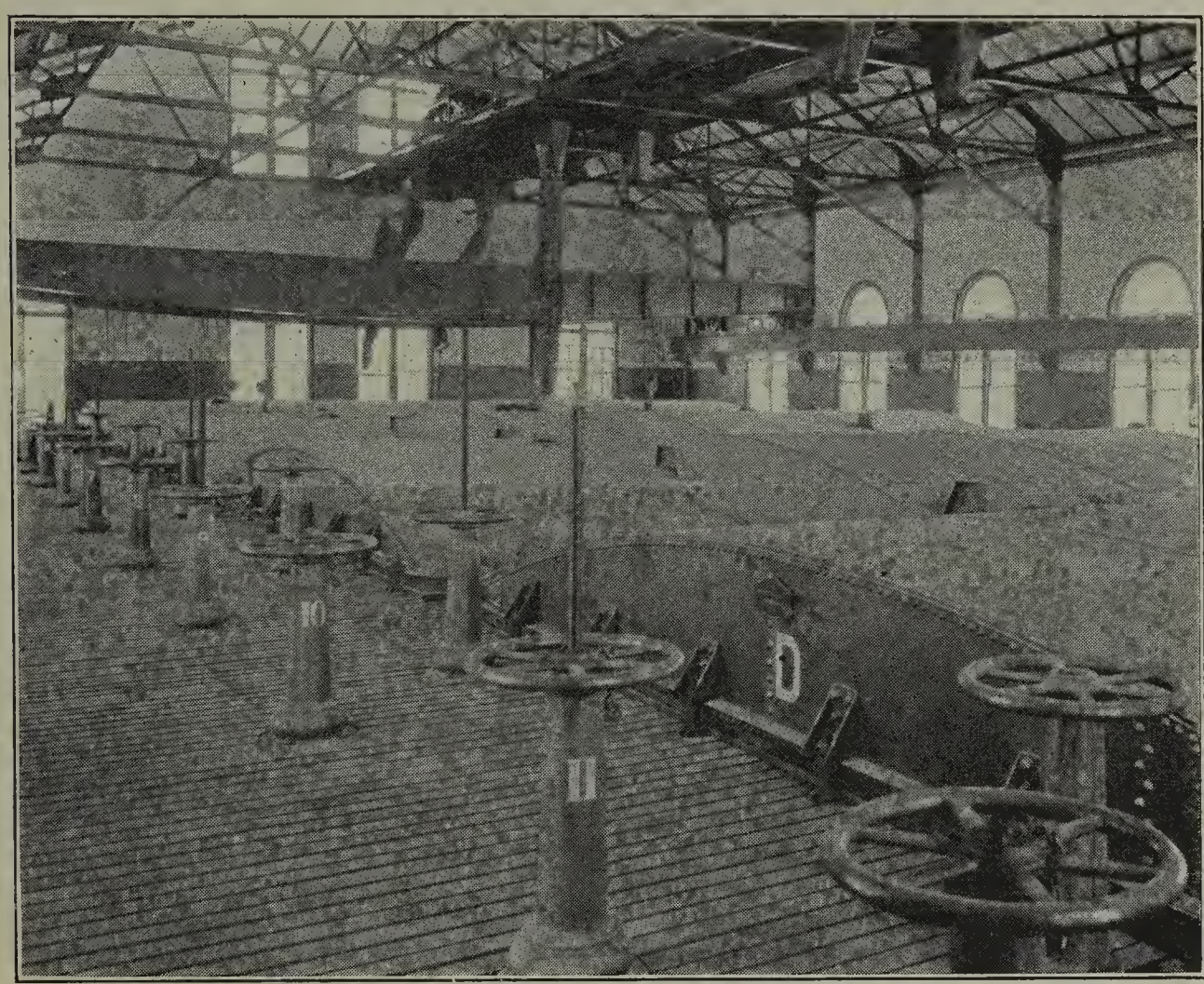

Fig. 15.—Water Gas Purifiers showing Belt Conveyor and Crane.

The purifiers are supported upon steel beams, girders and "H" columns.

For handling the purifier covers a traveling crane was provided operated by man hoists.

In filling boxes, oxide is dumped from wagons or wheelbarrows into a bucket conveyor, which transfers the oxide to the top of the building, dumping into a belt conveyor located at the bottom chord or roof truss and extending the entire length of the building. This

conveyor was provided with a tripper for discharging the oxide to either of the four sets of filling spouts located above the boxes. This apparatus is motor driven.

Meters—From the purifying house, the gas passes underground to the meter house. When the meter house was built, space was provided for four meters, only one being originally installed for coal gas. At the time of constructing the water gas plant, a 12-foot and a 14-foot Tufts meter with Hinman drums were removed from the South Station and re-erected in the present meter house, the gas passing through these two meters in parallel, thence passing to the mixing mains, where the coal gas and water gas were brought together and sent to the distribution holders.

Storage Tanks—One 500,000-gallon steel plate tank was removed from the South Station and two others were erected on concrete foundations over piling. Two tanks have been used for the storage of water gas oil and one for water gas tar. These tanks give a gravity flow to the oil and tar pumps. Oil is received by barges from an oil depot on the other side of the Bay and is pumped from the barges into the oil tank.

Tar Separators—The experience with tar separators has been somewhat unusual and has many points of interest. As originally laid out, the tar separating plant consisted of a reinforced concrete settling tank, 20 feet by 15 feet by 8 feet deep, and two separating tanks, 60 feet by 25 feet by 7 feet deep, followed by a cooling tank 52 feet square and carrying about 6 feet depth of liquor, the liquor finally passing through two coke filters and discharging into the Bay. The tar and water from the generator house, after passing through the seal pots on the machines, first entered the settling tank and then passed into a common header, which also received the tar and condensation from the other parts of the water gas plant. It then passed in parallel through the two separating tanks, thence to the cooling tank and from here the water recirculated through the various pieces of apparatus. This apparatus was never very satisfactory and did not give complete separation of tar from water. In addition, settling took place, so that the tanks cracked and leaked. In the summer of 1918, these tanks were waterproofed by means of a combination tar paper, pitch and sheet metal covering with a layer of concreting to hold and protect the waterproofing. This rendered the tanks waterproof and any further settlement is not feared. After studying the be-

havior of our tar and water emulsions, the following system was finally adopted: The first settling tank was abandoned, as apparently it served no useful purpose. The liquor from the wash boxes in the generator house was caused to pass into the first or right hand settling tank and double the original number of dams and baffles were provided; so that twice the separating effect was secured. The depth of liquor in the tanks were also increased about 15 per cent. The overflow from this tank, instead of going to the cooling pond, returned to the left hand or second separating tank.

The effluent from the tar extracting apparatus, condenser, exhauster house drips, etc., passed into a demulsifying chamber located at the entrance end of the second or left hand separator, where it passed over a series of steam heated pipe coils, thence discharging into the separator, where it mingled with the liquor coming from separating tank No. 1. The number of baffles and dams was also doubled in this second separator and the overflow from it went to the cooling tank and thence through the coke filters to the Bay. The water for circulation through the wash box, etc., instead of being taken from the cooling tank, was taken from the end or separating tank No. 1. It will readily be seen that several improvements have been made. The length of travel has been doubled by placing the separating tanks in series instead of in parallel and, in addition to this, the separating effect in each tank has been doubled by doubling the number of baffles. Furthermore, in as much as the circulating water is now taken from No. 1 separating tank. the flow through the second separating tank is greatly diminished, as the volume of material to be handled is very much less than if the circulating water was taken from the outlet end of the whole system. The system as finally adopted has worked with great satisfaction, although, due to the forced employment of an inferior grade of oil during the past year, it has not been possible to secure water gas tar having a low moisture content, but the separation of tar from the circulating water is practically perfect.

The accompanying illustration (Figure 16) shows the general layout of this apparatus. We are now using the first settling tank for storage of drip oil, etc., which we use in our boilers. The black solid lines show the flow of tar and water as now operated. The double lines show the original connections, which are not now in use.

Gas was first made in this plant December 1, 1916. The rated capacity of each of the machines is three and a half million cubic feet per day. It will be apparent that with the completion of this water gas plant, the combined capacity of water gas and coal gas at the close of 1916 was very nearly equal to double the average daily output and that no further extension of water gas capacity was likely to be needed for a number of years to come. This plant is the latest complete water gas plant to be erected in New England and is thought to represent the most advanced practice in

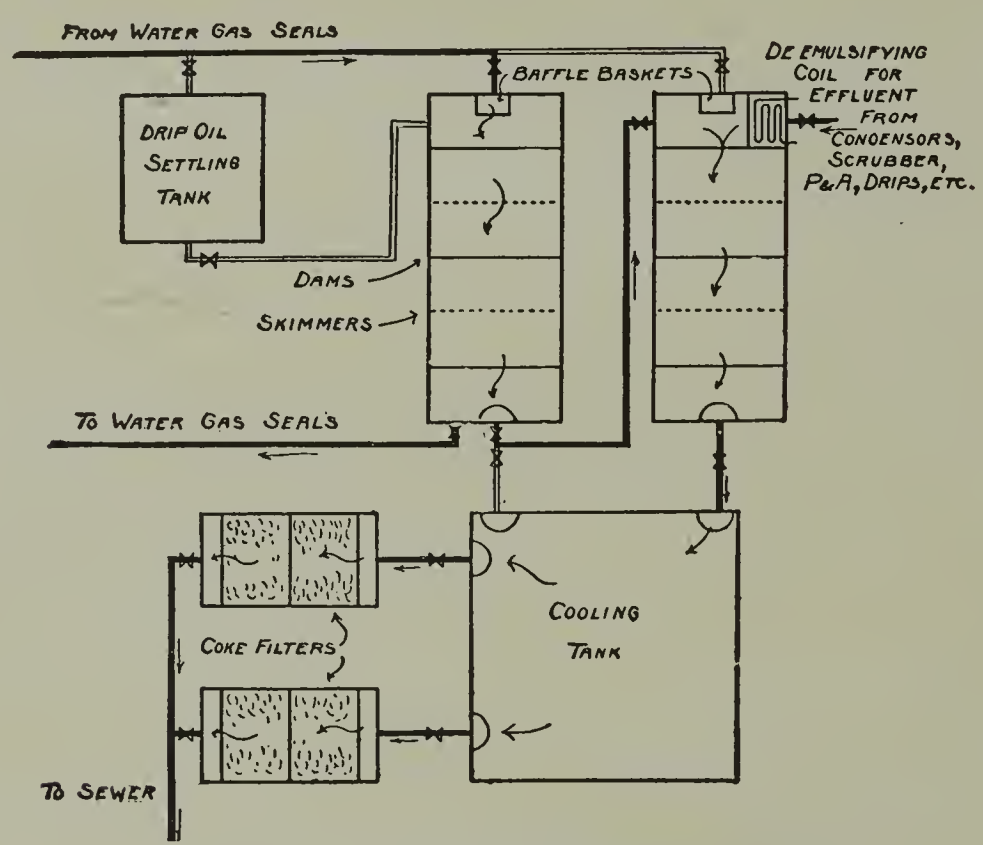

Fig. 16.—Diagram of Tar Separating System.

its general constructional details and has certainly operated with credit to the Engineer of the Gas Company and the Engineers of the contractors involved in its construction.

Koppers Coke Oven Plant

As early as 1914 the Engineers of the Providence Gas Company felt that the Dessau vertical coal gas plant should never be extended in case additional coal gas equipment was needed; in fact, it was even recommended that that plant be abandoned and a new plant of Woodall Duckham vertical retorts be built in its place. After having had an opportunity to study the Dessau vertical

plant for several years, it appeared that American conditions were so very different from European conditions that a type of plant which had proven successful abroad might not be so in this country. In 1914 the vertical retort had not been developed in this country to the extent that it now has, particularly in the use of silica material and labor saving devices. Therefor, the abandonment of the vertical retort plant at Providence must not be taken as a condemnation of the system or even of this particular plant. In April, 1917, a report was made, recommending that a coal gas plant of 6,000,000 cubic feet daily capacity be built. Careful study was made of the existing types of plants in the United States. At about this time, Mr. John R. Freeman was elected President of the Gas Company, and during the year 1917 also was appointed as the Company's Engineer. By the time Mr. John R. Freeman had become President of the Company, the growth of the business was such that any system other than bulk carbonization appeared unsuited for this plant, which eliminated from consideration even the highly successful vertical retort plants typified by the works in Rochester, N. Y. In November, 1917, after an exhaustive study of the whole situation, Mr. Freeman brought in a report, recommending the construction of a Koppers combination gas oven plant with a nominal capacity of 700 tons of coal a day, and this plan was formally adopted.

Installations of Koppers ovens at St. Louis, Missouri, and the Seaboard By-Product Coke Company, Jersey City, New Jersey, had been serving their respective cities with a part of the gas from the carbonized coal and had demonstrated the feasibility and value of such an operation. It was considered impossible, in the case of Providence, to operate a straight coke oven plant successfully, as the volume of coke for sale per thousand cubic feet of gas sold appeared to be excessive. In the other installation of Koppers ovens, where the gas was used for city purposes, it was the rich portion of the gas which was so distributed, the lean portion being used to heat the ovens. The first intention was to build ovens at Providence which could be operated only as producer gas fired ovens, but later this plan was changed and it was decided to build a combination gas and coke oven which could be operated as a gas or cake oven. A single collecting main only was supplied. Therefore, all of the coal gas, both the rich and the lean, is mixed at the collecting main and delivered through the plant to the storage

holder. Gas can be taken from the storage holder and returned to the battery, being burned in the flues by means of the ordinary gas burners supplied with standard Koppers combination ovens. Also the ovens can be operated on producer gas. One of the reasons why this decision was arrived at was that it was intended to build a by-product producer gas plant and there were certain possibilities connected with starting up such an installation which made it advisable to have the alternative feature as a matter of safety and insurance for continuity of operation.

Also should the market for coke ever become capable of absorbing at a sufficiently high figure the entire output of the battery operating on its own gas, the water gas plant could make up the deficiency of coal gas output thereby occasioned.

As there were no Koppers ovens operating in the United States on producer gas, it was necessary for the Koppers Company to make a comparatively complete new design, particularly with reference to that part of the oven below the sole flue, including the regenerators, producer gas and fuel gas mains and passages and the apparatus for their control. Thus, this battery of ovens as it stands to-day represents something entirely distinct from any other plant yet built in the United States but it has already demonstrated its value and justified the faith of the builders, and it will undoubtedly prove the forerunner of a series of such installations.

It was at first intended to erect a battery of producers to operate on coke breeze and small coke. These producers would probably have been of the well known Kerpely type, which has proven so successful in foreign Koppers oven installations. The writer first became associated with this project in the latter part of 1917 and brought to the attention of the Company's Engineers the great possibilities of the bituminous coal producer, particularly when operated on by-product recovery, citing the well known examples of such practice in England. A careful investigation of the possibilities of bituminous and by-product producers was undertaken and, after a long series of experiments, investigations and consultation with the foremost gas producer builders and producer gas engineers in the United States, a contract was finally given to the Wellman-Seaver-Morgan Company for five producers and to the Steere Engineering Company for the equipment for cleaning, cooling and preparing the gas for use in the ovens.

The Wellman-Seaver-Morgan Company's engineers brought out

an entirely new design of gas producer intended to operate on bituminous coal, either with by-product recovery or without, depending on the depth of fuel bed and other special details. The Steers Engineering Company proposed a gas cleaning plant similar in many details to plants which they had already put in successful operation and also including some new and novel conceptions.

Owing to changes which were made by the Gas Company in their plans late in 1918, it was not possible to complete the producer

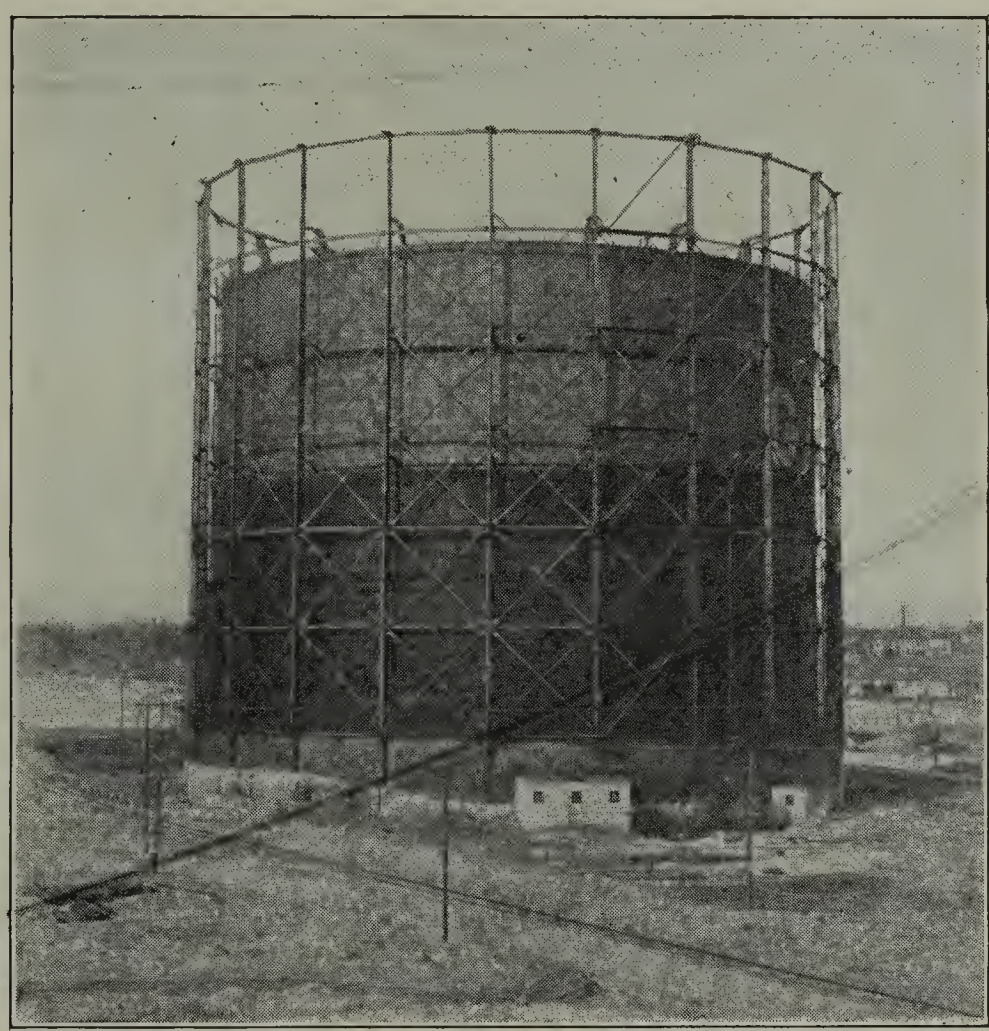

FIG. 17.—Six Million Cubic Feet Holder erected by Bartlett Hayward Co. in 1911.

gas plant in time for it to be used for the first few weeks' operation of the ovens and they were, therefore, started up and run for a few weeks on run of oven gas; thus demonstrating their flexibility and adaptability to widely different conditions of operation and fully justifying the expenditure for including the combination feature.

Patriotic conditions played no small part in forming the decision to adopt a coke oven plant. At the time the contract was let, the United States Government was experiencing a severe short-

age of foundry coke and lent considerable assistance toward the construction of this plant, with a view to taking over its entire output of coke immediately on its completion. The uses of the War Department would also have provided an outlet for its production of aqua ammonia from the coke oven gas, sulphate of ammonia from the by-product producer plant and the light oil products from the benzol plant. As the plant did not begin to turn out coke until January, 1919, the demands of the Government no longer existed and other outlets for its products are being found.

In addition to the building of a battery of ovens and the extension of the coal and coke handling apparatus and the apparatus for treating the coke oven gas, many other improvements to the plant had to be undertaken during the past year, which included the erection of a coal store for boiler coal, an administration building, a stocking or rehandling pit for railway coal, the installation of four Coxe stokers for handling inferior grades of boiler fuel, the installation of a new feed water heater and the construction of a storage battery plant to provide power for peak load demands, in addition to the regular output of the works private power plant.

These minor additions to the works equipment will be discussed before the description of the oven plant proper, as they were in a sense preliminary to it.

Stocking and Rehandling Pit—In years past, almost all fuel for the gas was received by boat, but disturbed transportation conditions during the year 1918 caused a great deal of all rail coal to be brought to it. Ordinarily this all rail coal could be handled direct from the cars by means of the telpher buckets, but the above mentioned unusual conditions made this impossible. A concrete pit was, therefore, constructed at a convenient place under the telpher lines, so that two cars of coal could be discharged by means of hopper bottoms or side dump chutes onto an inclined plane, which carried the coal into a pit directly under the telpher rail, where one or more telpher buckets could readily obtain access to it. This pit has been in constant use during the past year.

Administration Building—The development of the Manufacturing Department and the unusual amount of repair work during the past year for rehabilitating the plant required more extensive shops and offices than existed. In addition plans were in process of formulation for the development of by-product business and for very careful chemical control of the plant. When the Sassafras

Point Works was first built, a portion of the meter house was used as an office and works laboratory, but this was entirely inadequate for the past year and was also situated at a considerable distance from the heart of the works.

It was, therefore, decided to remodel an existing building, the foundations and roof of which lent themselves to such a project. A brick building was, therefore, constructed, containing basement, first and second floors, which is 144 feet long and 40 feet wide with an ell 31 feet wide and 144 feet long. The basement contains a shop for the repair of automobiles, ample storage room for

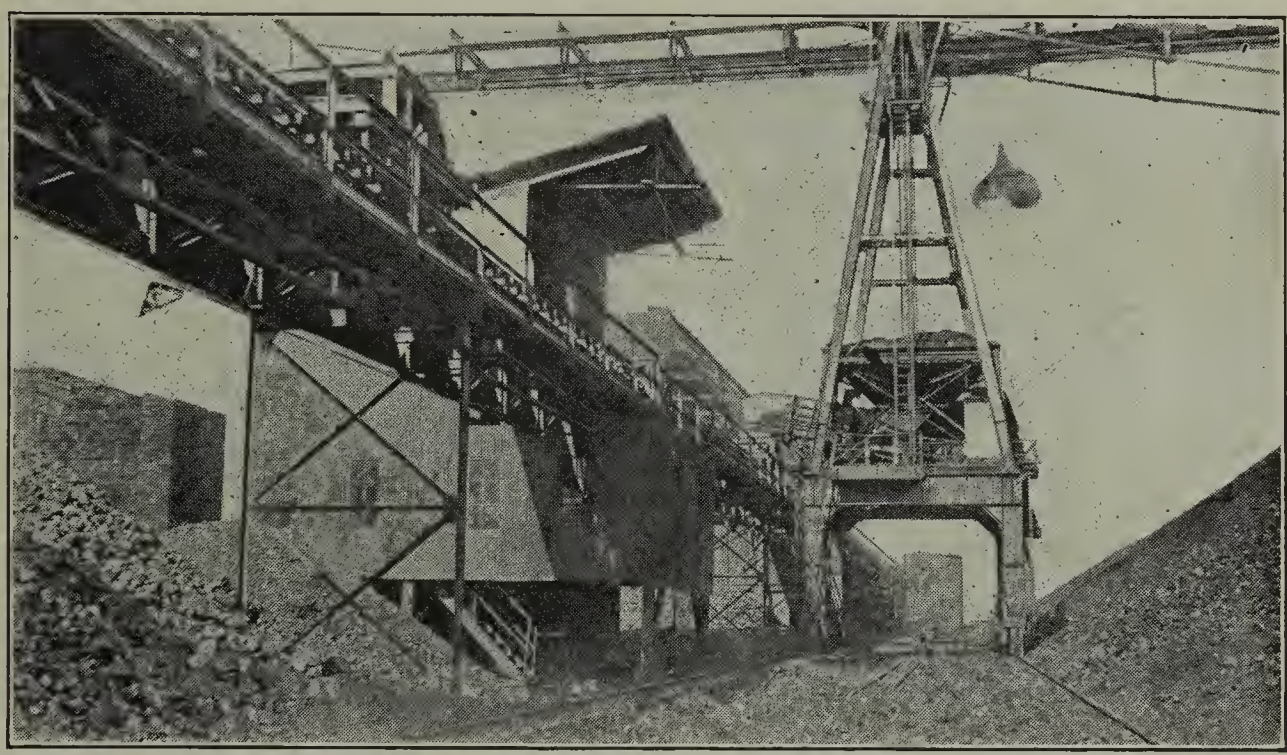

Fig. 18.—Coal Belts Alongside Coal Dock and Rehandling Plant.

heavy machinery and parts and very complete lavatories and locker rooms for the shop and office employees. On the ground floor are the Superintendents' and Engineers' offices and a well equipped machine shop, forge shop and carpenter shop. On the second floor are several large rooms which are now unoccupied but which will later be used for the service of the distribution department. On this floor, there is also an instrument room for the storage and care of all sorts of instruments used about the works, library and museum, main chemical laboratory, photographic dark room, photometrical laboratory, coal grinding and sample room, mechanical drafting room and Construction Engineers' offices.

All parts of the works are connected with the Administration Offices by means of an intercommunicating Select-O-Phone system.

Coal Handling—A receiving hopper was constructed on the coal bridge to work in connection with a 36-inch belt feeder conveyor. Coal dropped into this conveyor is delivered to conveyors running alongside the coal pile. There are two of these conveyors, serving the entire length of the coal pile, some 460 feet, the transfer station being located near the middle of the coal storage space. (Figure 18.) These 30-inch belt conveyors carrying traveling chutes, which take the coal from the feeder conveyor on the

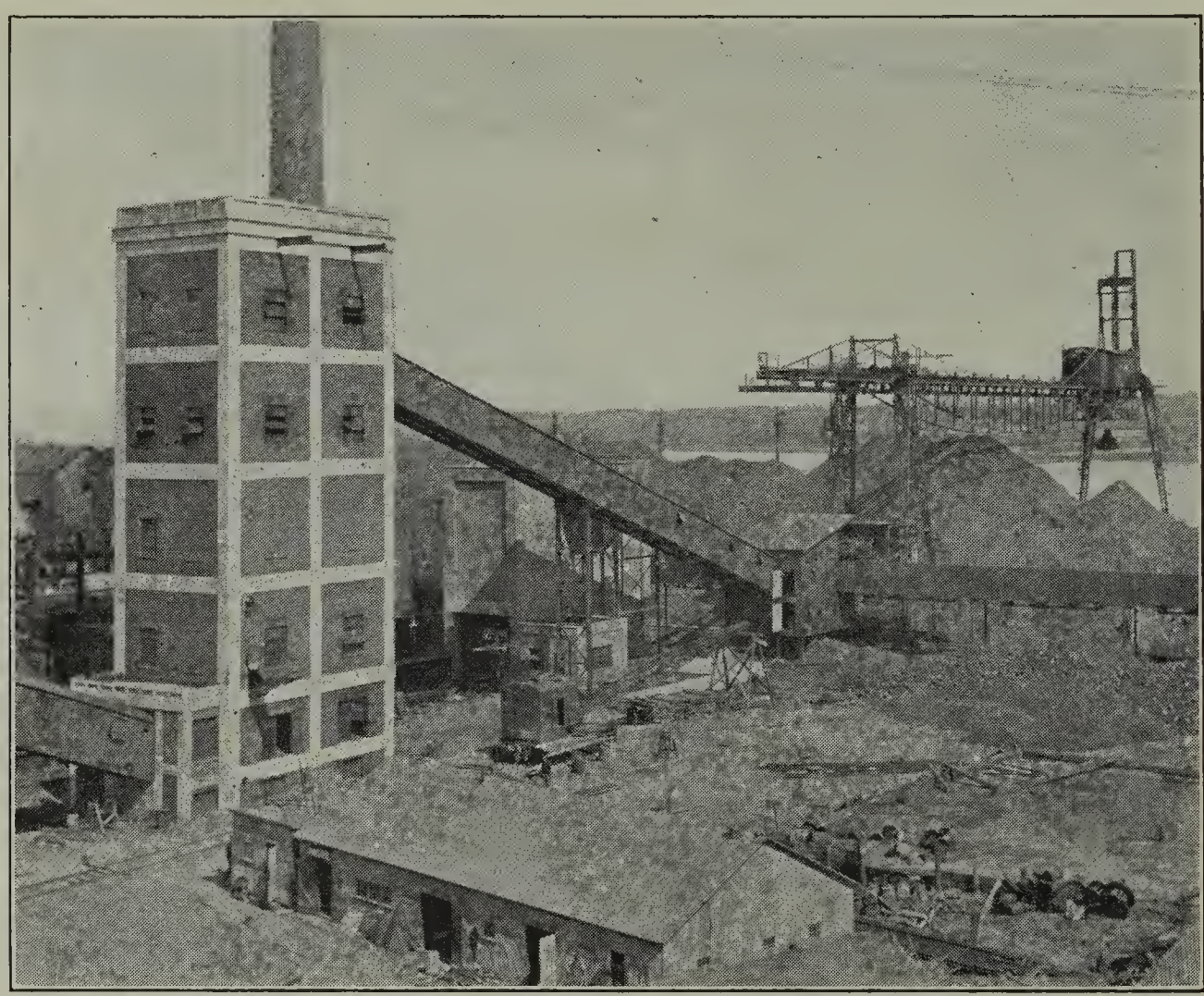

FIG. 19.—Coal Crushing and Mixing Building and Conveyors.

bridge. The longitudinal belts deliver to a 30-inch belt conveyor, which takes the coal from the transfer tower to the top of the coal mixing and crushing house. (Figure 19.) The conveying machinery for coal and coke was furnished by the Robins Conveying Belt Co.

This mixing and crushing building is of reinforced concrete construction with red brick panels and contains a Bradford breaker, two mixing bins, each of 100 net tons coal capacity, a refuse bin of 50 tons coal capacity, a coal mixer and a hammer mill with the

necessary electric motors and accessories for the operation of the coal machinery. The outside of the bin walls are faced with common red brick. Steel sash window frames and steel doors are provided. The coal bins are lined with reinforced glass.

The coal coming up from the transfer station is delivered to a 12-foot by 14-foot Bradford breaker, where the coal is broken to approximately 1½-inch size, dropping into either of the two bins. One bin is used for high volatile and one bin for low volatile coal. The coal drops from the bins through two chutes onto two coal mixing belts, where the coal is mixed, passing thence into a hammer mill or crusher with a capacity of 100 net tons per hour. This hammer mill may be by-passed, if it is not desired to pulverize the coal. The crusher and Bradford breaker were furnished by the Pennsylvania Crusher Co.

From the hammer mill or the by-pass, the coal drops onto a 24-inch belt conveyor, which delivers the coal to a transfer tower, thence onto another 24-inch belt conveyor to the top of the coal storage bin.

The coal storage bin is built of reinforced concrete and has a capacity of 750 net tons of crushed coal. It has steel sash window frames with double strength glass and steel doors. The hoppers in the bin are lined with glass, and in the bottom of the bin are twelve hoppers arranged in three rows of four, each hopper being provided with a cast iron duplex gate for charging coal into the larry car. The bin is divided into two parts by a partition, so that two kinds of coal may be in storage at the same time, such as straight high volatile or high and low volatile mixture of any desired proportion. The panels on the building are filled with common red brick. A stairway is provided for access to the various parts of the building. (Figure 20.)

When using a mixture of high and low volatile coal for making foundry coke or hard grades of domestic coke, the hammer mill or crusher is used and the coal is delivered to the coal bin pulverized so that from 60 to 85 per cent. will pass a ⅛-inch mesh screen.

When using the straight high volatile coal, it is sometimes desirable to have much coarser coal and the hammer mill is then by-passed. The capacity of the coal handling equipment is such that 700 tons or a full day's run of coal may be put through the plant and into the storage bins in ten hours. It is apparent that

should the capacity of the plant be doubled at any future time, the coal handling equipment is sufficient to care for this increase.

Oven Battery—There are forty Koppers Patented, Cross Regenerative, Combination, By-Product Coke Ovens built in one battery, resting on a reinforced concrete pad, with reinforced pinion walls at each end. The ovens have a capacity of 11.4 net tons each and are 37 feet long from face to face of doors, 9 feet 10 inches

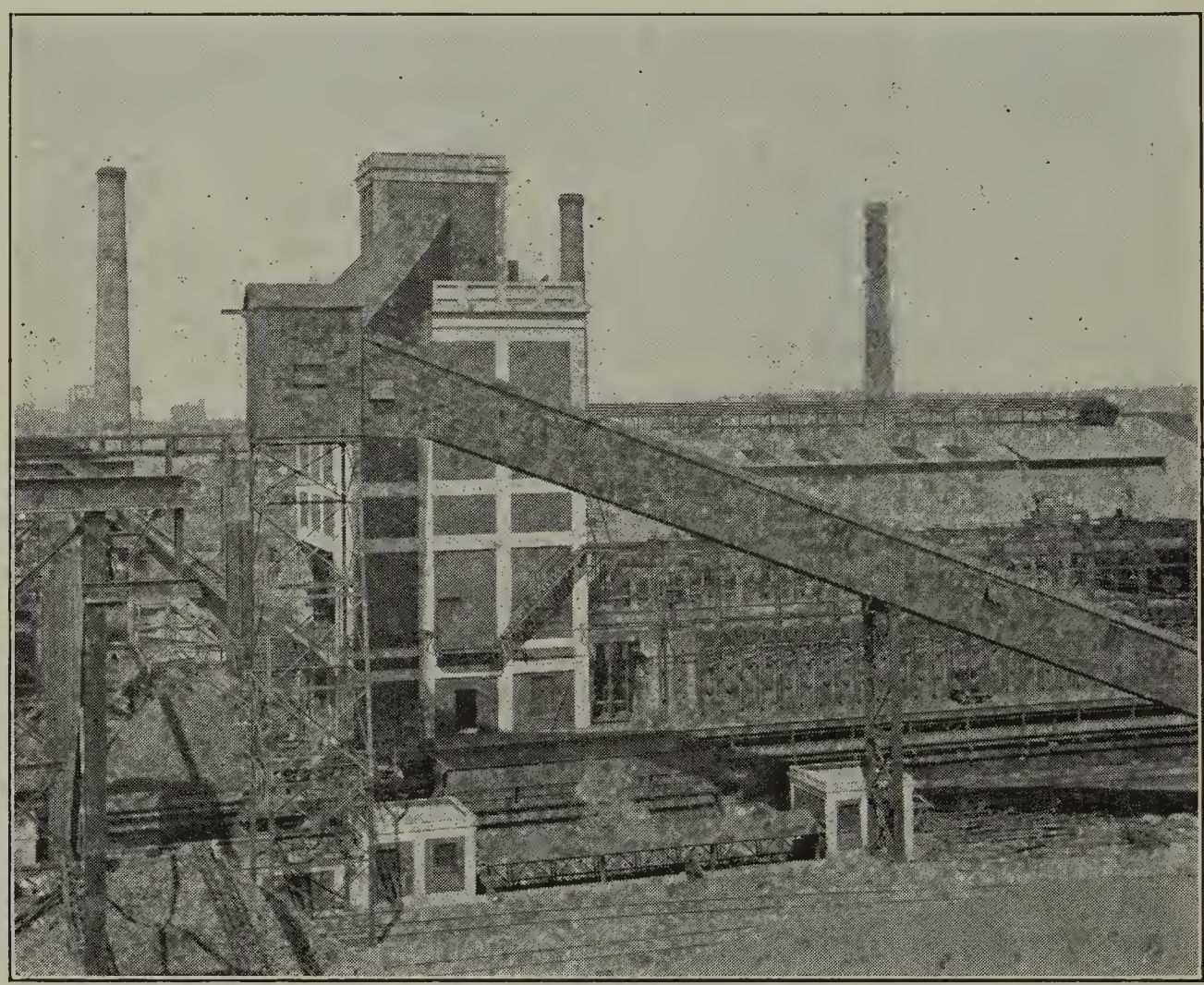

FIG. 20.—Coal Bin. Ovens and Conveyors. Coke Wharf In Foreground.

high, 15¾ inches wide at the narrow end and 18¾ inches wide at the wide end. The ovens are 3 feet 6¼ inches from center to center. All oven brickwork exposed to high temperature is silica, the secondary portions being firebrick. Common brick is used to face the regenerators and as fill above the ovens, and the tops of the ovens are covered with paving brick.

The ovens are designed to be operated either as coke ovens, using part of the run of oven gas in the heating flues, or as gas ovens, using producer gas generated in an independent producer plant from coal or coke and are designed for a 15-hour coking time.

Under each oven is a double regenerator, the walls between the double regenerators being built under the vertical heating flues and being very heavy and tight. Lengthwise through the center of the regenerator runs a light division wall. There are two lines of ports entering each flue chamber, one from each of the adjoining regenerators.

One double regenerator is entirely given over to the preheating of the air for combustion, the air from one side of the central

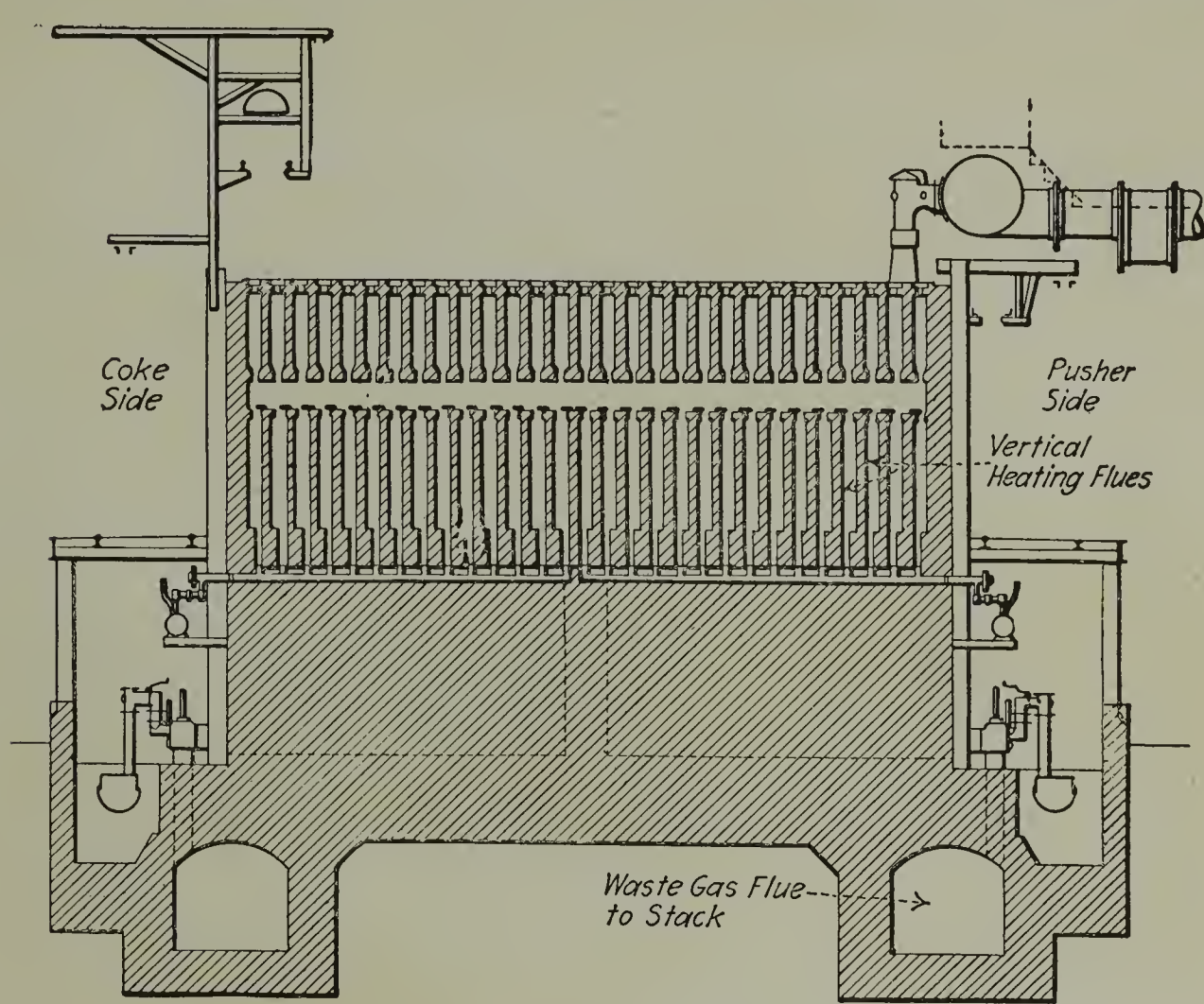

FIG. 21.—Section through Heating Flues.

division wall going to one set of flues and that from the other side to the next set of flues. The next adjacent double regenerator preheats the producer gas and distributes it in a similar manner, the gas from one side of the central division wall going to one side of the oven and from the other half going to the other side. Thus, any leakage through the narrow division wall is of no importance, as air and gas are separated by the heavy walls under the flues. (Figure 21.)

When using run of oven gas, the divided regenerators are used for air only. The oven gas is supplied through a fuel gas

main feeding risers which serve the gas ducts just under the flues. This duct is divided into two parts, each serving approximately one-half the oven flues from opposite sides of the battery. At the base of each flue is a removable nozzle, through which the burning gas issues. (Figure 22.)

Combustion is regulated by means of a system of sliding bricks acting as dampers on the vertical flues as they lead into a horizontal flue. Each flue may be regulated independently. Also dampers are provided to regulate the draft in each regenerator outlet. The

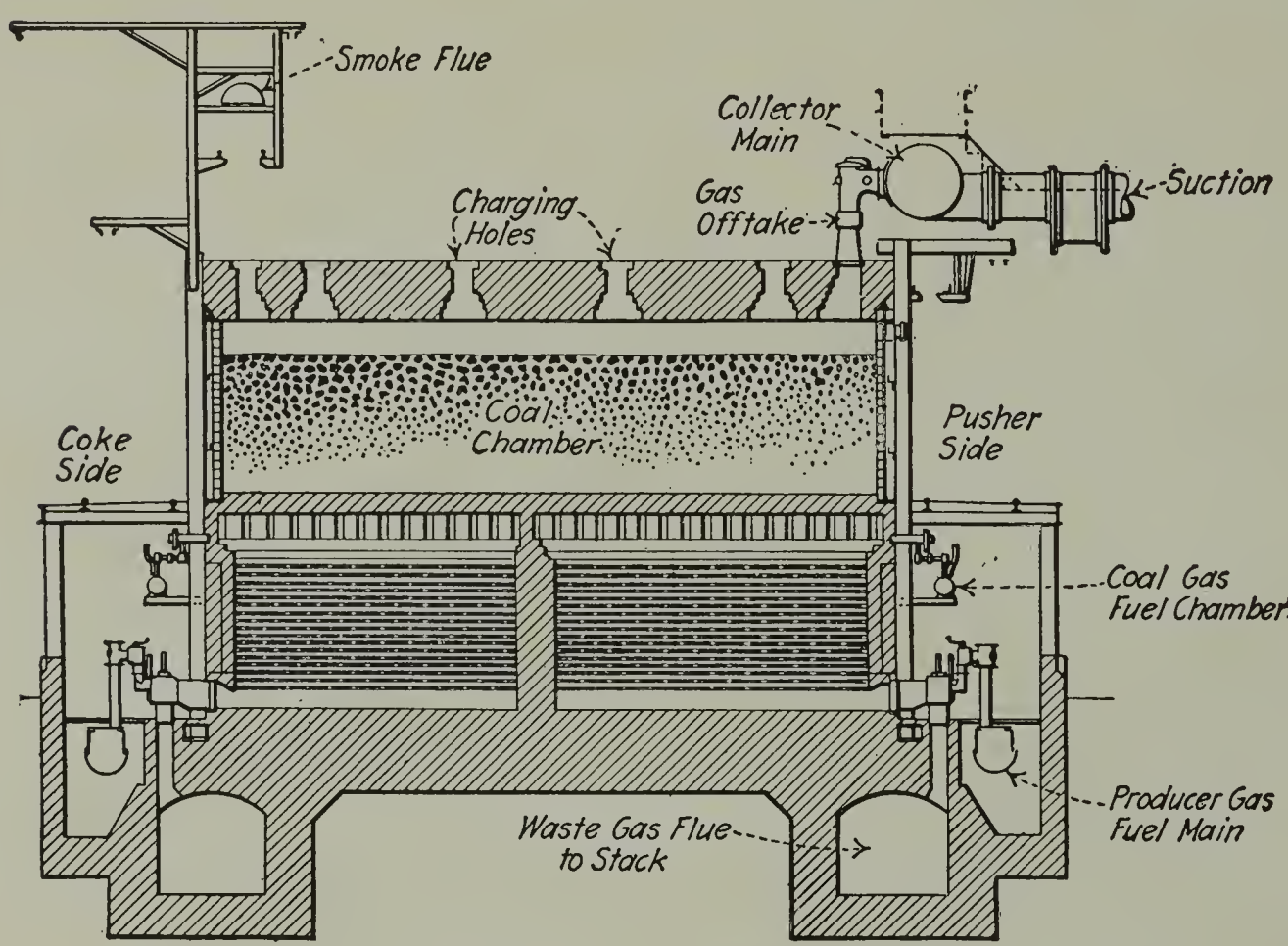

FIG. 22.—Section through Ovens and Regenerators.

gas burns in one-half of the flues at a time on one side of the battery, the products of combustion rising to the horizontal flue, passing to the other half of the battery, down through the vertical flue to the regenerators, to the main flue, to the stack. Thus, the regenerators are reheated by the products of combustion on alternate sides of the battery.

The direction of flow of the oven or producer gas is reversed automatically through the system of burners, flues and regenerators every thirty minutes. Thus, the regenerators return to the flues a large amount of heat which would otherwise be wasted.

The nozzle through which run of oven gas burns is located midway between two rectangular ports, each serving one-half of a regenerator. When using oven gas, it is not advisable to supply air for combustion to each nozzle from both sides; so it is considered good practice to close with a brick one of these openings, allowing the air from only one opening to mingle with the gas for combustion. The next adjacent gas nozzle is served with air from the opposite side; so that the placing of the bricks closing off the air ports from the regenerators is in a sort of staggered formation. On the other hand, when producer gas is used, the gas nozzles play no part and are closed and the bricks covering the alternate regenerator ports are removed, and in any given heating flue, one line of ports feeds gas from one-half of a double regenerator and the other line of ports feeds air from the regenerators.

Draft for the ovens is provided by a red radial brick stack 7 feet 6 inches inside diameter and 200 feet high. There is a main stack damper, a regulating damper for each flue, serving the two sides of the battery, and a system of reversing valves and dampers. The reversing is done automatically. A time clock, which may be adjusted for any given reversing period, actuates contact devices, which set in motion electric motors, which, in turn, operate the various apparatus concerned with reversal.

When run of oven gas is being used to heat the battery, the reversing machine operates the gas cocks on the run of oven gas lines, but when producer gas is being used, the cocks on the run of oven gas line remain closed all the time, and the reversing mechanism operates the valves on the producer gas lines, handles the dampers on the flues, opening one and closing the other for reversing the flow of products from one side of the battery to the other side, and also, at the proper time, opens the wind boxes which supply the air to the regenerators. (Figure 23.)

The oven doors on the pusher side have a secondary leveling door at the top. All doors consist of a cast iron frame lined with firebrick. These doors on the coke side are handled by a Koppers door-lifting machine operated by electric motors.

For pushing the coke out of the ovens, a combined pusher leveler and door-lifting machine is employed, carrying a ram which pushes the coke from the oven, a motor rope driven leveling bar to level the coal in the ovens, a door ram to remove the oven doors and a carbon scraper. (Figure 24.) On the coke side, there is a door

machine, which handles the doors, and a coke guide, which is constructed of steel and which directs the movement of the coke across the coke bench into the quenching car. The coke is received in a coke quenching car with a capacity for one oven, which has air operated cylinders for opening the doors. (Figure 25.) The bottom of the car is lined with cast iron plates and the ends of the car with steel plate. This car is handled by a 15-ton electric loco-

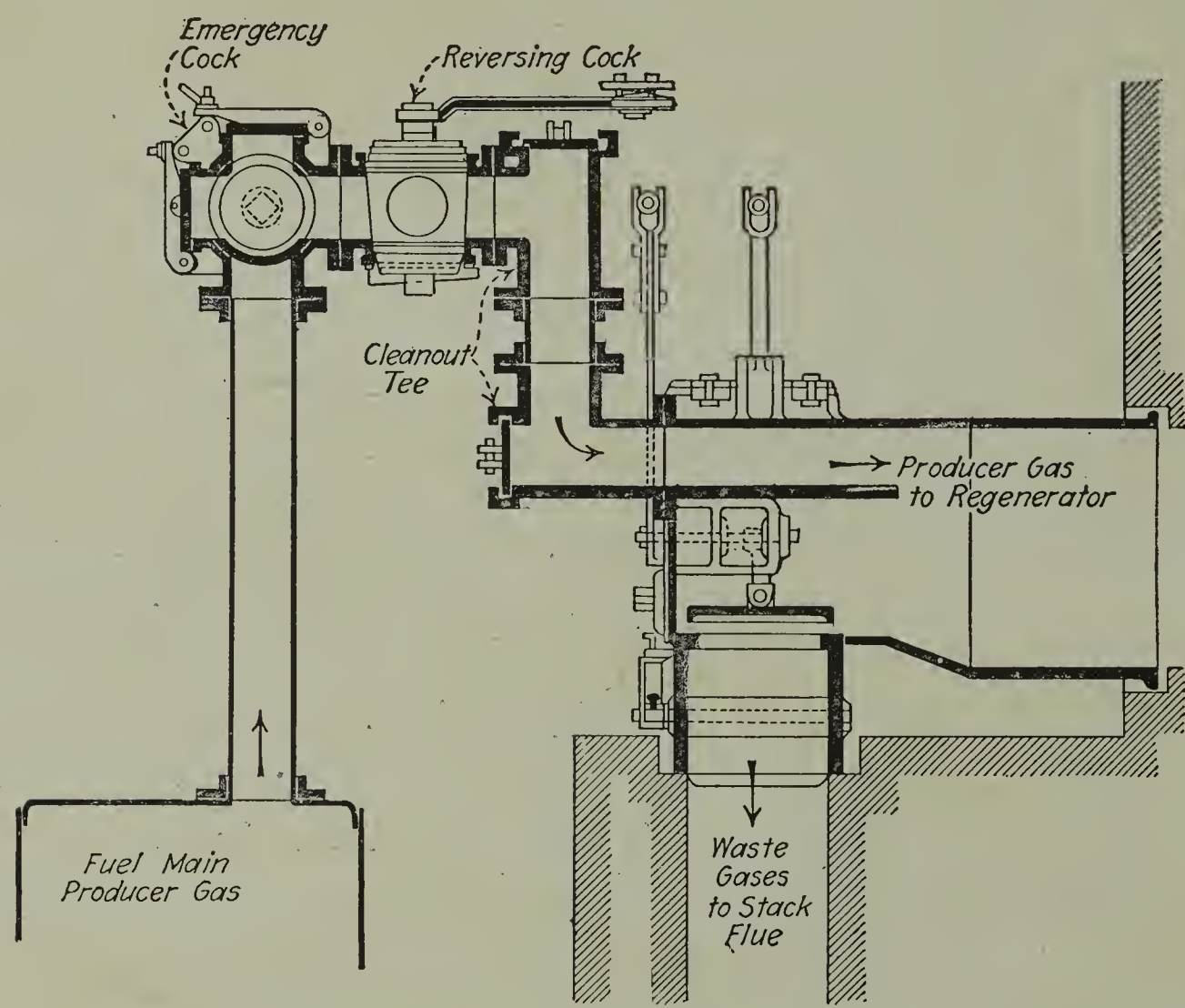

Fig. 23.—Produces Gas Valves and Ducts.

motive. After the coke is received in the car, it is taken to the quenching station.

For charging the coal into the ovens, there is provided a coal charging larry, electrically driven, which has four coal hoppers made of ¼-inch steel plate. (Figure 26.) During the charging of the oven, a sort of valve comes down on the coal hole frame, which largely prevents smoke from escaping at this point. The smoke flue extends the entire length of the coke side of the battery and connects with the battery stack. A telescopic pipe mounted on a carriage can be used to connect the smoke offtakes of any oven

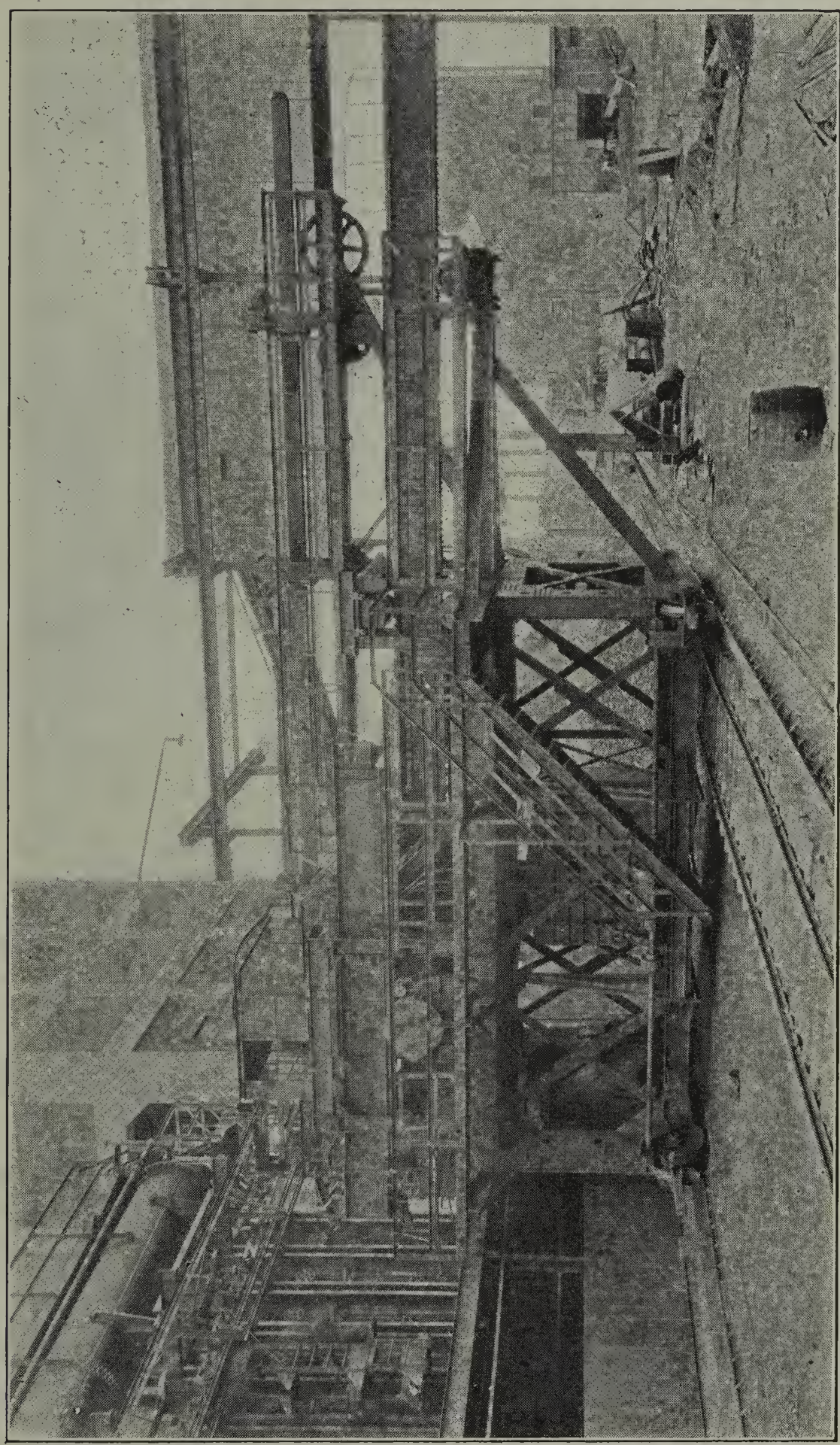

FIG. 24.—Coke Pusher and Leveler.

to any smoke flue through a mushroom valve acting in connection with telescopic pipe mounted on a carriage. Most of the smoke generated during charging can be drawn up through this telescopic pipe into the smoke flue and thence to the stack. The operation of removing the doors, pushing the coke, replacing the doors, charging the coal, leveling same and replacing coal hole lids is accomplished very smoothly and quickly with a minimum of disturbance. Three clay carriers are provided—two on the coke side and one on the pusher side—and as fast as the oven doors are replaced,

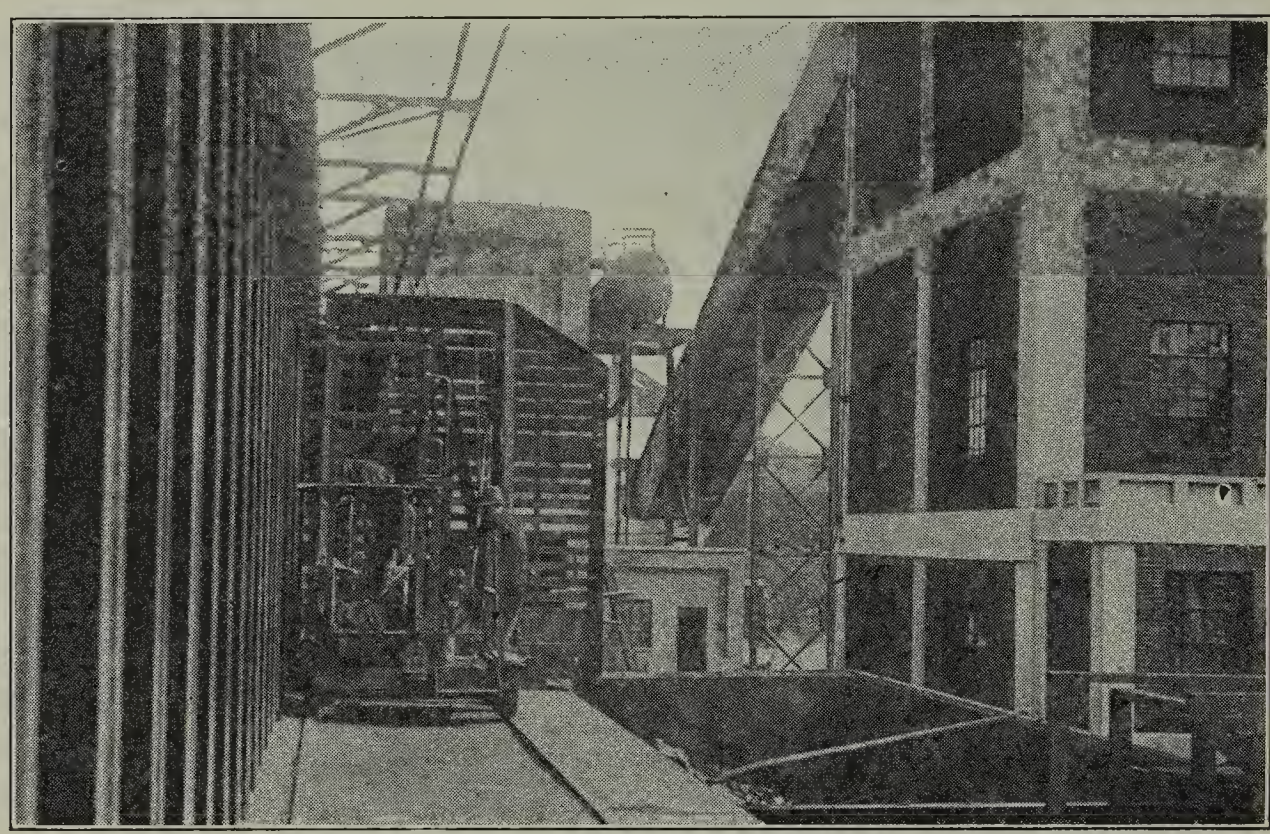

Fig. 25.—Mud Car, Coke Guide and Coke Quencher Car.

they are luted with clay, which is prepared in a clay mixer located under the coal bin.

The run of oven gas, after passing through a wet meter, is brought back to the battery through a 12-inch fuel gas main, a short pipe running from this main to each gas burner, the gas burners being provided with shut off cocks, carbon caps, etc.

From each oven a short 13-inch cast iron ascension pipe carries the gas from the ovens to the gas collecting main. In the upper section is a butterfly valve and a cleaning door, the ascension pipes entering the collecting main at one side. The collecting main serves the entire battery and is circular in cross section, 54 inches in diameter, sloping from each end to the center, at which point the

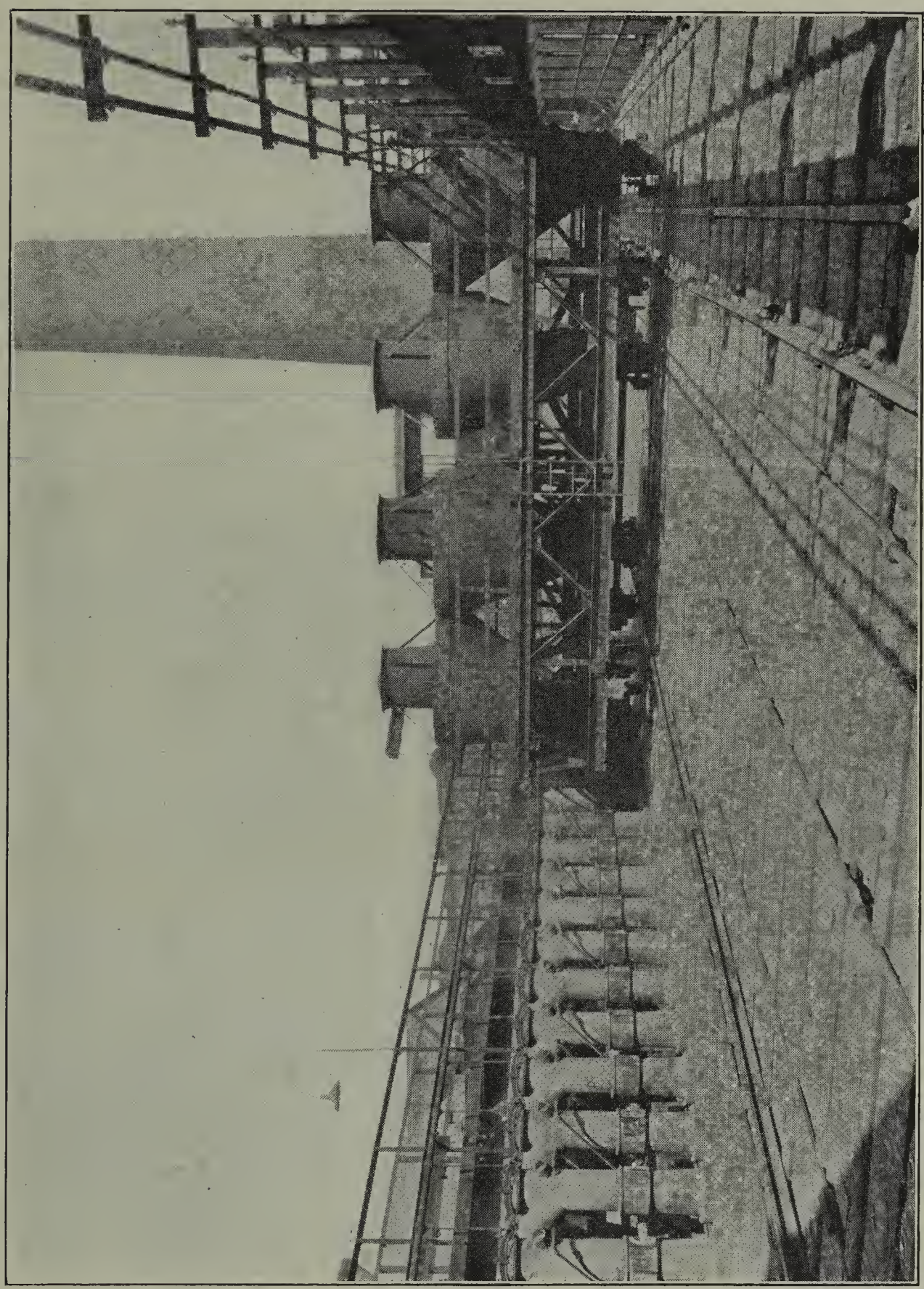

FIG. 26.—Larry Car and Top of Ovens.

offtake main connects. This main is provided with the necessary cleaning holes and is built of 3-inch steel plates with a walkway on the top. Sliding plate dampers are provided each side of the offtake main, so that one-half of the battery may be cut off at a time. The offtake main is 30 inches in diameter and is built up of riveted pipe. This main runs over to the producer house wall, supported on a steel bridge. The gas then passes into a down-comer, which is built of two vertical cylinders, one telescoping the other, the outer portion being 4 feet 4 inches in diameter and 10 feet long, with a conical bottom, dipping into a seal tank. The inner portion is 30 inches in diameter and 8 feet 9 inches long. The condensates from the gas and flushing liquor pass down through the down-comer into the pitch trap and seal tank. The gas passes from the inner pipe to the opening at the top of the larger portion, thence through 30-inch riveted pipe from the top of the down-comer to the ground, then underground to the by-product house. A circulating tank 15 feet in diameter and 9 feet high built of steel plate with a partition is located at the yard level, this tank being used for supplying tar and liquor for flushing purposes.

Coke Handling—The coke, which is received in the quenching car, is carried to the quenching station, which consists of a quenching and settling basin and a quenching tank. The hood is 20 feet wide and 50 feet long and has a total height of 60 feet, being built of brick, open at one end only, so that the quenching car can enter. The water tank is of steel and has a capacity of 7,500 gallons, being supported overhead on a steel framework about 60 feet from the ground. A spray pipe is located under the quenching hood. Two motor driven pumps are provided for handling the quenching water, which is recirculated from the sump through the settling basin, etc. The sprays have quick-opening valves and discharge the contents of the tank in 35 to 60 seconds. The coke car, after having received the charge of quenching water, is drawn out from the hood and allowed to stand a few minutes for draining, the drained water running back into the sump. A small amount of makeup water is required each day to take the place of steam driven off. The quenching hood being some 60 feet in height throws the rush of steam and vapor high above the yard level. After standing the necessary time, the coke is drawn along the coke road to the coke wharf, which is at the opposite end of the

battery from the quenching station. This coke wharf is 48 feet long and is built of reinforced concrete with cast iron plates and is provided with finger gates and feeders. The coke is fed onto a 36-inch belt conveyor, with a capacity of 210 tons per hour, which runs alongside the coke wharf, then rises to the foundry screening station. The foundry screening station is built of reinforced concrete with red brick panels. The run of oven coke is delivered by the belt conveyor to a rotary grizzly, from which a 36-inch shuttle belt conveyor delivers the foundry coke to open top coke cars on a railroad track alongside. The smaller sizes of coke dropping through the grizzly fall onto a belt

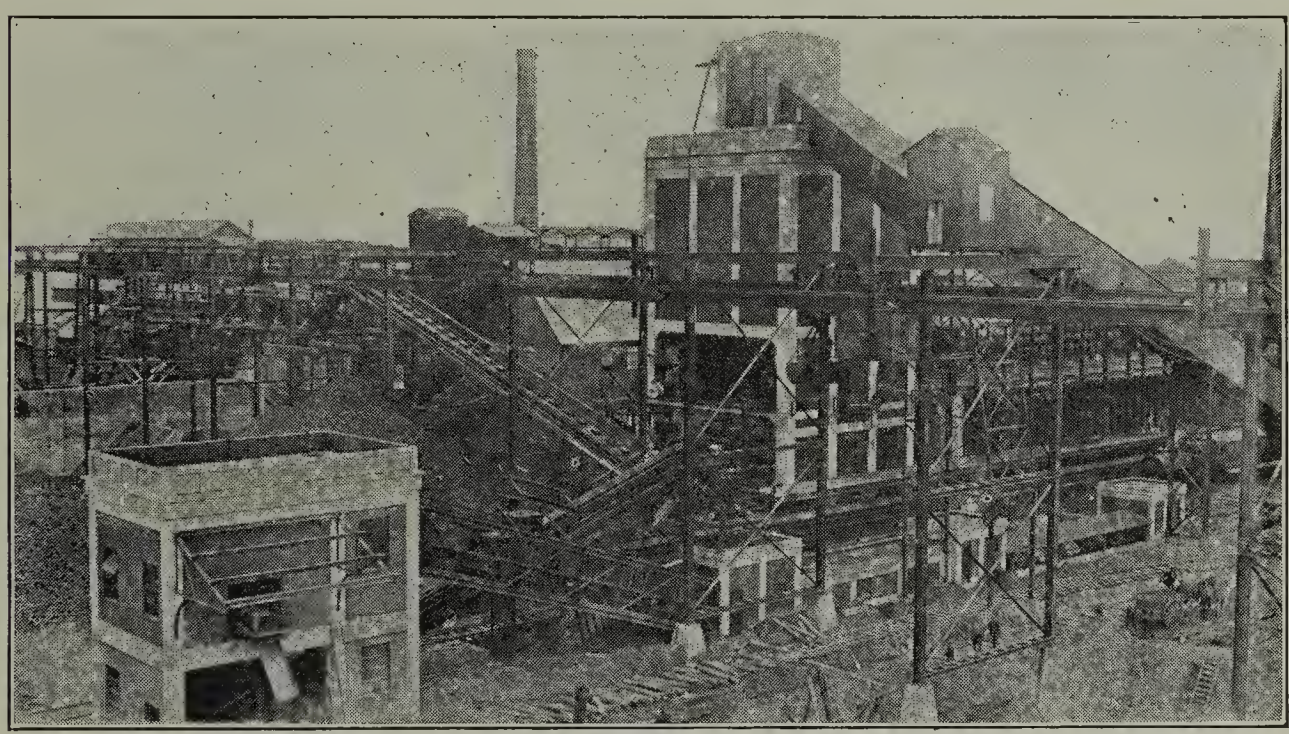

Fig. 27.—Coke Handling Apparatus.

conveyor, which ascends to a transfer station, then transferring to another ascending belt rises to the elevation of the telpher lines, passing along under the telpher lines. (Figure 27.)

Under the telpher lines is a system of rotary grizzlies, which may be operated in several ways. The egg, stove, nut, pea and breeze coke come first to a rotary grizzly which takes out the egg and drops it into a bay underneath the telpher lines, from whence it can be rehandled. The coke then passes to a second set of grizzlies, which takes out the stove size, which likewise falls into its proper bay. The nut, pea and breeze then go on a belt to a pit or bin adjacent to the screen houses, where they are, in turn, deposited. From this pit either one of two telphers can pick

them up and send them to either of two shaker screen houses, where they are separated into their respective sizes.

Likewise, should the storage piles be full or if, for any other reason, it is undesirable to separate the egg and stove on the rotary grizzlies, these can be by-passed and all sizes go to the pit, from whence they are sent through the shaker screen houses.

This makes a very flexible arrangement, so that if the shaker screen houses are down for any reason, the production of egg or stove size is not stopped, as the rotary grizzlies can take care of this; also should the egg and stove piles be well filled under the rotary grizzlies, the shaker screen houses can be called upon to make all five sizes of coke.

In addition to the above arrangement, when foundry coke is not being made or if it is desired to send run of oven coke direct to railroad cars, plates may be put on the grizzly; so that all the coke will drop onto the shuttle belt which goes to the cars. If it is desired to make all domestic coke and no foundry, the foundry grizzly is run but the large sizes which go over this grizzly and drop onto the shuttle belt are carried to a coke crusher. By reversing the direction of this shuttle belt, this coke crusher breaks the large sizes into domestic sizes, which, dropping through the crusher, are caught on the same belt which is handling those sizes of coke which fell through the foundry grizzly, and thus the whole output of coke in domestic sizes is carried up to the rotary grizzlies under the telpher lines, where egg and stove are prepared and also, by the shaker houses, the net, pea and breeze sizes of coke.

It will be noted that great care has been taken in arranging the coke handling system to avoid tie-ups due to any particular set of conditions, and it is believed that this arrangement will take care of the entire output of coke from the ovens without further additions for sometime to come.

The run of oven coke carried by the belt to the foundry screen house is automatically weighed by a Merrick weightometer; so that an accurate check is obtained on the yield of coke from the coal daily.

After the coke is passed through the shaking screen stations, it drops into bins, from which it can be chuted directly into trucks or wagons or handled into cars, trucks or wagons by the telphers.

A large amount of coke is also handled in paper bags and canvas bags. Small size coke for domestic use is delivered in can-

vas bags, which are filled in the screening station and placed on a roller conveyor, which automatically transfers them to a wagon loading house, which is 90 feet long and 29 feet wide and which will provide ample storage for bags and from which as many as sixteen teams may be loaded at one time. In all as many as forty teams and trucks can be loaded with bag and bulk coke in different parts of the yard, which is ample for the domestic trade anticipated.

For loading foundry coke, one shuttle belt loader combined with a box car loader will take care of one car to be loaded as the coke is made. Locomotive cranes can also load from storage piles. On the north side of the producer house is a set of track hoppers served by the telpher lines, from which coke may be loaded into four cars at a time for railroad shipment. In addition to this, it is planned to put bins for loading at least two cars under the telpher lines in other parts of the yard, so that in all, including foundry coke and domestic sizes, as many as eight railway cars of 30 to 40 tons capacity can be loaded at any given time.

Condensing and De-ammoniating Plant—The condensing plant built by The Bartlett Hayward Company for handling the 3,000,000 cubic feet of retort gas consisted of water tube condensers, P. & A. tar extractors and rotary scrubbers. This equipment has been utilized exactly as it stood with the exception of a few minor changes in the movement of scrubber water, liquor, etc. A new exhauster was added, making three in all. Two are used with the third as a spare. There was ample room in the building for the addition of this third exhauster.

It became necessary to provide gas treating apparatus for 4,000,000 cubic feet of gas to take care of the total of 7,000,000 which it was contemplated the new coke ovens would produce. (Figure 28.) Various systems were considered. Had the conditions in the industrial world been normal and the prices such as to make the investment reasonable, it is probable that a complete new by-product plant would have been built, probably of the Koppers system, but funds were not available for such a development at the time and it was felt that the extension of this part of the plant must be made as economically as possible. The Steere Engineering Company of Detroit, had in the past few years developed a system of handling gas for condensing and deammoniating, which had previously attracted the writer's attention and which appeared to be a

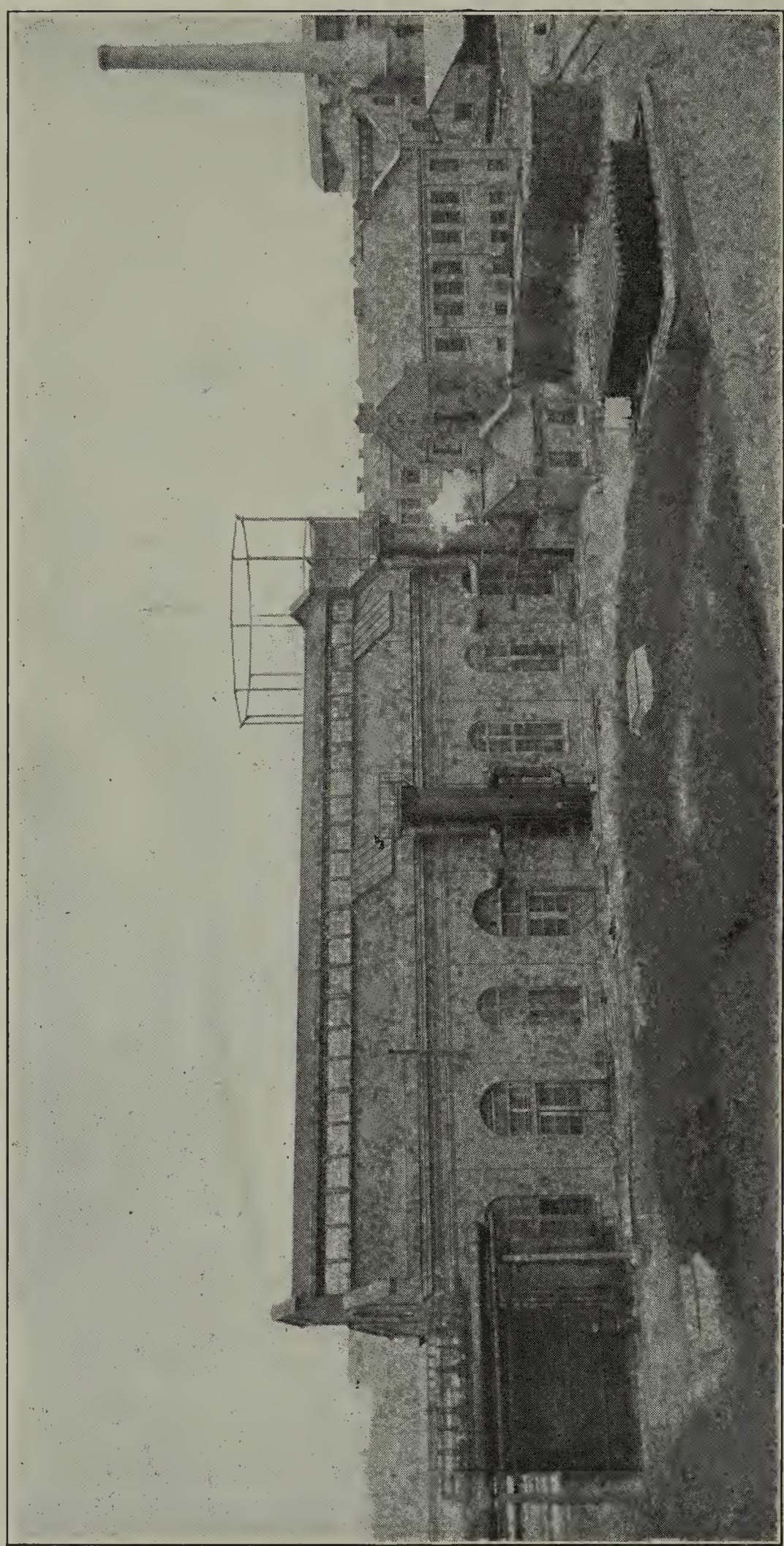

FIG. 28.—Extension of Condensing Plant.

possible solution of the present problem. The Engineers of the Steere Engineering Company were invited to study the local situation and prepare plans for condensing and de-ammoniating equipment, which were duly completed and submitted and, with some slight changes, accepted by the Company. The gas coming from the ovens in an underground main divides between the old primary condensers and the new Doherty washer cooler as designed by the Steere Engineering Company. This Doherty washer cooler consists of a steel plate shell 5 feet in diameter and 29 feet high, packed with wooden grids after the manner of the tar scrubber. Over these grids liquor is circulated by means of electrically driven centrifugal pumps. The gas then passes through the exhausters and tar extractors and again divides, the proper proportion going to a secondary Doherty washer cooler, where the temperature is brought down as low as 60° F. if desired. The wash liquor which is pumped over the grids in the washer coolers goes from the base of the coolers through a series of cooling coils, which are set up in a convenient location adjoining the building. Cold water runs down over these cooling coils from suitable troughs and the cooling of the recirculating wash liquor is thereby quickly and economically affected by means of direct contact between the cold incoming wash liquor and the gas. Very complete transfer of heat is secured and the heat potential is much less than with multitubular water condensers.

The operation of these washer coolers is highly satisfactory. The condensed liquor and tar from these coolers forms a surplus, which overflows from the base of the scrubbers through a seal to the main tar liquor separators for the ammonia storage wells. After leaving the secondary washer coolers, the streams of gas again come together and pass through the old Feld washer, thence through the two rotary scrubbers and finally through the intensive scrubber supplied by the Steere Engineering Company. This intensive scrubber is 15 feet long, 6 feet 6 inches wide and 22 feet high and contains four compartments filled with wooden grids, over which the wash liquor is circulated by means of four motor driven centrifugal pumps. Fresh water is admitted to the last compartment and the wash liquor is recirculated in this compartment, then passing progressively through each of the other three compartments, finally discharging to a tank in the condenser house, underneath one of the rotary scrubbers. From this tank

the liquor is picked up and recirculated through the two rotary scrubbers, the effluent discharging into a second tank located underneath the other rotary scrubber. From this tank liquor is picked up by a steam pump and recirculated through the Feld washer, the final effluent discharging into the main ammonia storage well.

This system of recirculation of the ammonia liquor results in scrubbing out considerable portions of hydrogen sulphate and carbon dioxide in combination with the ammonia gas and is remarkably efficient in recovery of ammonia. Tests shows that when using 1½ gallons of water to a thousand cubic feet of gas, not more than 1 grain of ammonia per 100 cubic feet of gas is lost at the outlet of the intensive scrubber. The liquor through the entire plant, including suction main, condensers, washers and scrubbers, may be made of any desired strength between 1 and 2 per cent. by varying the amount of fresh water entering the intensive scrubber. Although the washer cooler and intensive scrubber appear very small in size for the work which they have been called upon to do, careful tests show that they are amply large and since starting up have worked with great satisfaction.

Producer Gas Plant

As is very well known, during the early part of the year 1918 there was a great shortage and demand for all products of ammonia. This fact was well recognized by the Engineers of the Gas Company and influenced them in deciding upon by-product recovery producers. After the order had been given for the producers and before the details of the cleaning and ammonia extraction plant were worked out, this demand ceased and the original plans were not carried out. The plant as it is now, therefore, consists of by-product producers which may be operated either with or without by-product recovery and a set of apparatus for cleaning and cooling the gas, which has been considerably modified and simplified from the original design, although the plant could readily be converted for ammonia recovery, should it so be desired at any time in the future.

Gas Producers—The gas producers are five in number and were built by the Wellman-Seaver-Morgan Company. They are designed to produce gas from bituminous coal either with or without recovery of ammonia; or to produce gas from coke. Generally

speaking, these producers are a modified form of the standard Hughes producer, the principal difference being in the maximum depth of fuel possible and the massive size of the machinery column, stirring mechanism, etc. (Figure 29.)

In a casual observation, an engineer familiar with gas producers is immediately struck by the great height of this apparatus. The distance from the floor line to the top of the producer is 20 feet 9 inches; from the top of the air inlet or tuyere in the lower part of the producer to the under side of the top, 10 feet, which would allow a fuel bed of 8 or 9 feet in depth, including the ash and clinker zone. The inside diameter of the steel shell of the producer is 11 feet 6 inches and there is a 9-inch fire brick lining, which reduces the diameter to 10 feet. (Figure 30.)

When operating for plain gas production, the producer shell is rotated at a speed of one revolution in ten minutes. If it is desired to operate for by-product recovery, this speed will be cut in half. The ash pan is free to revolve independently of the shell but, owing to the presence of ashes in the pan, it revolves with the shell, due to the binding action of the wet ashes. In order to keep the ash bed and lowest zone of the producer in a free condition, it is arranged to have this ash pan take an intermittent retrograde movement with reference to the producer shell. This is secured by means of two trippers set 180° apart, which, by striking a stop, cause the ash pan to rotate for a few inches in a direction opposite to the rotation of the producer shell.

Coal is fed to the producers from an overhead coal bin by means of a gas tight measuring feeder, which is operated by the motor driving the rest of the producer mechanism and can be adjusted through a wide range of speed in feeding. For stirring the fuel bed, a long poker is provided, which is dragged through the fire in a direction approximately at right angles to the direction of rotation. On No. 1 Producer there are two pokers—a long and a short—which would be used in all the producers should they be operated for by-product recovery with a deep fuel bed. When using a deep fuel bed, the long poker stirs the zone just above the ashes and the short poker penetrates about 2 feet below the top of the coal. The other producers are equipped with a single poker only but the poker shaft is arranged to take the second short poker at any time desired in the future. (Figure 31.)

These producers are blown with air saturated with steam, the

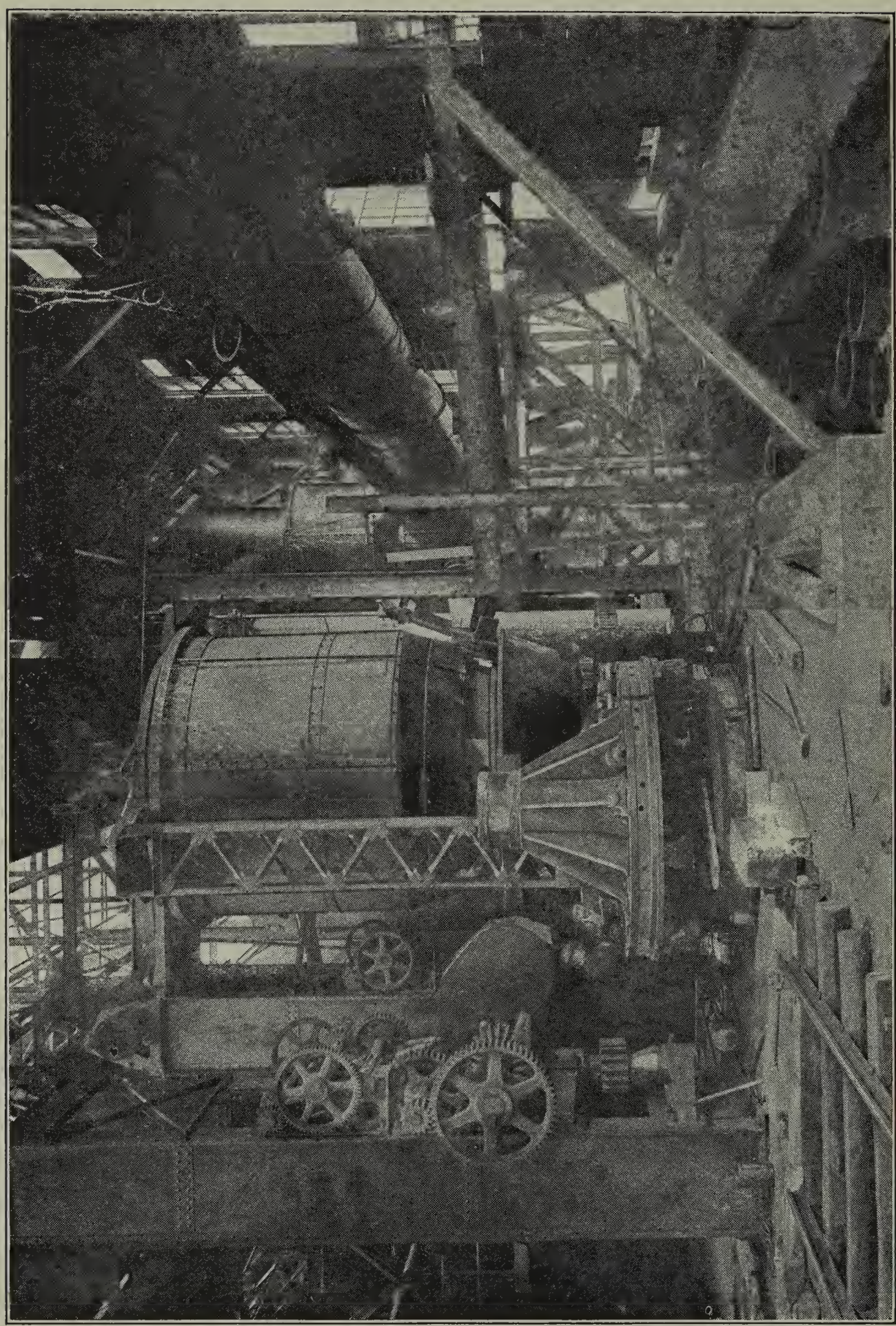

FIG. 29.—Gas Producers and Accessories.—Duringer.

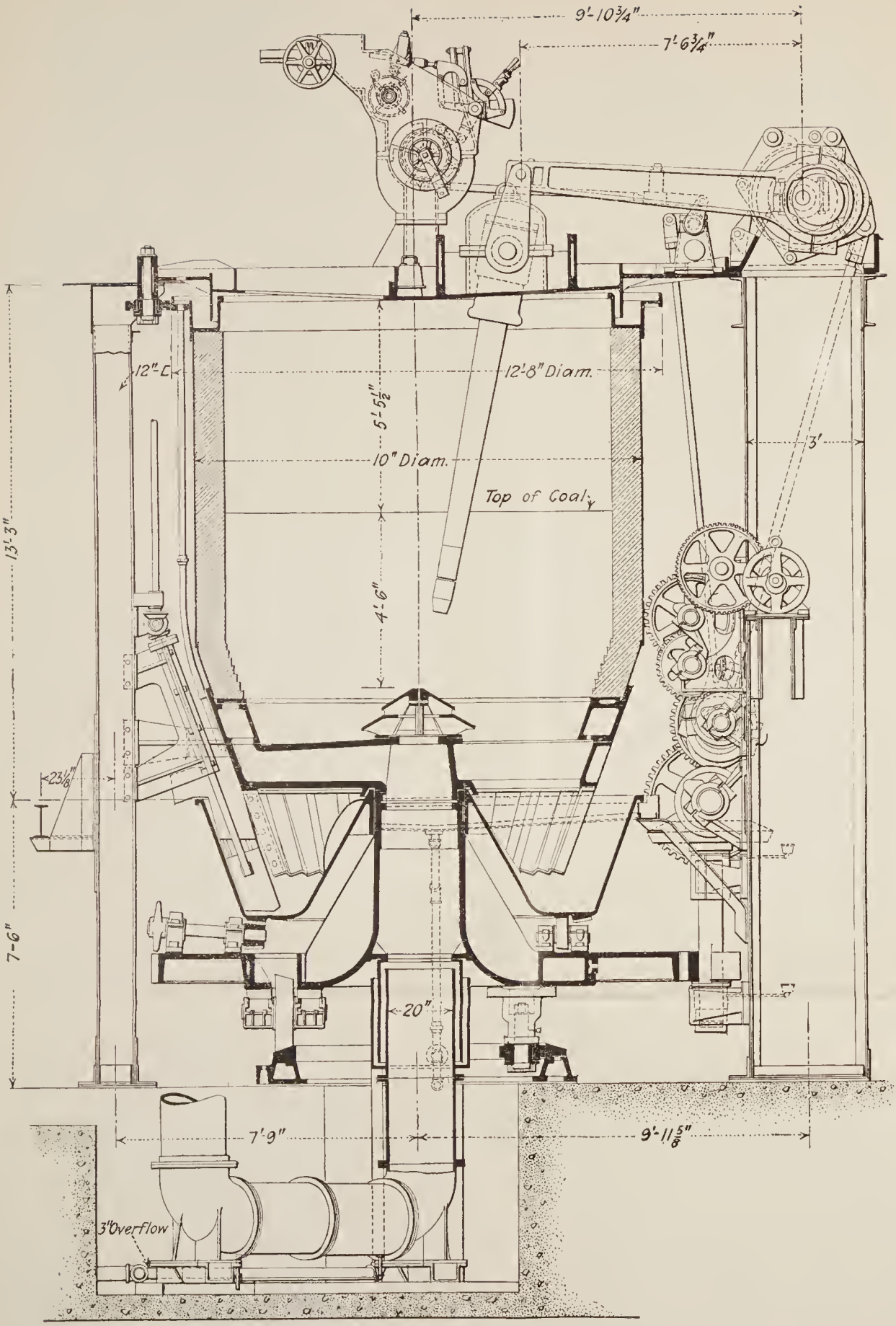

Fig. 30.

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Hot Gas Producer. Shallow Fuel Bed. Single Poker.

air being furnished by Coppus steam turbine blowers at pressures running from 8 inches to 24 inches, depending on the depth of fuel, depth of ash zone and other conditions. The exhaust steam from these blowers goes into the blast air and additional steam is also admitted under careful control; so that the temperature of the blast air is an indication of the amount of steam being used. This temperature may be 140° to 150° F. more or less, depending on conditions, and this represents something like 1.2 pounds of steam per pound of coal gasified.

Air is admitted to the center of the producer through a double headed tuyere and also by means of a hollow spider the air is admitted at the sides of the producer in order to obtain an even distribution of air. The producer house is arranged for six producers, and should the plant operate for ammonia recovery, it is probable that six would be needed, five only being installed at the present time, which it is felt is ample for the heating of the forty coke ovens operating on 15-hour coking time, running four producers with one idle for cleaning or repairs.

Roughly speaking, about 100 tons of bituminous coal of good quality must be gasified to heat the battery when in full operation. If ammonia recovery is practiced, probably not over 20 tons of coal will be gasified per producer per day. On the other hand, when operating with a shallow fuel bed without recovery of by-products, it is believed that three producers are entirely sufficient, in as much as 35 tons of coal have been successfully gasified in one producer in 24 hours.

In the first weeks of operation it was found that the B.t.u. of the gas varied from 135 to 175 B.t.u., depending on depth of fuel, amount of steam, blast pressure, etc.

The oven battery is so designed that all or any part of the battery may be heated with producer gas, and a great deal of experimental work has been done in determining the range and capacity of the different parts of the producer gas plant by varying the number of ovens heated from one producer and also varying the coking time; thus demonstrating the extremely flexible arrangement of the combined producer gas and run of oven gas system for heating the coke ovens.

Gas Treatment—The preparation of the gas for use in the coke ovens requires removal of dust, pitch, tar and a large portion of the moisture and heat, the maximum desirable temperature at the

outlet of the fuel gas holder being in the neighborhood of 100° F. This problem was given to the Steere Engineering Company of Detroit, who designed, built and installed all of the cleaning apparatus, acting also as engineers and erectors on the producer gas plant as a whole. The major portion of the apparatus was designed in line with the standard practice of the Steere Engineering Company for clean producer gas plants, several improved and new features were introduced.

Dust Catcher—The gas leaving the producer has a temperature of 1100° to 1300° F. and is laden with coal dust, soot and pitch. It first enters a dust catcher (one of which is provided for each producer), where a sharp and sudden change in the direction of the gas is caused, precipitating the dust to the bottom of the dust catcher. To accelerate this action, a heavy spray of hot water enters the dust catcher and strikes the inner cone, dropping thence to the bottom and washing out dust, etc., into a concrete separator.

Each dust catcher discharges its gas into a common collection main running the entire length of the battery of producers. In this main the gas is also heavily sprayed with hot water, the overflow running to the concrete decanter or separator. The gas issues from the collection main at a temperature of 165° to 175° F.

Barbotage—From the collection main the gas enters the barbotage, which is a long rectangular steel box open at the bottom and sealed in the water in the decanter. (Figure 32.) Inside of this box is another steel box with swinging sides, having serrated edges, the serrations dipping into the water. The gas comes into this inner box and is wire drawn over the surface of the water through the serrations. These swinging sides are balanced by weights and the differential through this apparatus remains the same when changes in the amount of gas passing occur as, when the gas flow increases, the balanced vanes are blown outward, thereby opening a larger space for the gas to pass through in the serrations but maintaining the same relative action. On the other hand, if the gas flow diminishes, the swinging vanes come inward, decreasing the opening in the V-shaped serrations and again adjusting the wire drawn effect to accommodate the amount of gas passing.

The barbotage is equipped with sprays for use when necessary. At times dust accumulates on the surface of the water and inter-

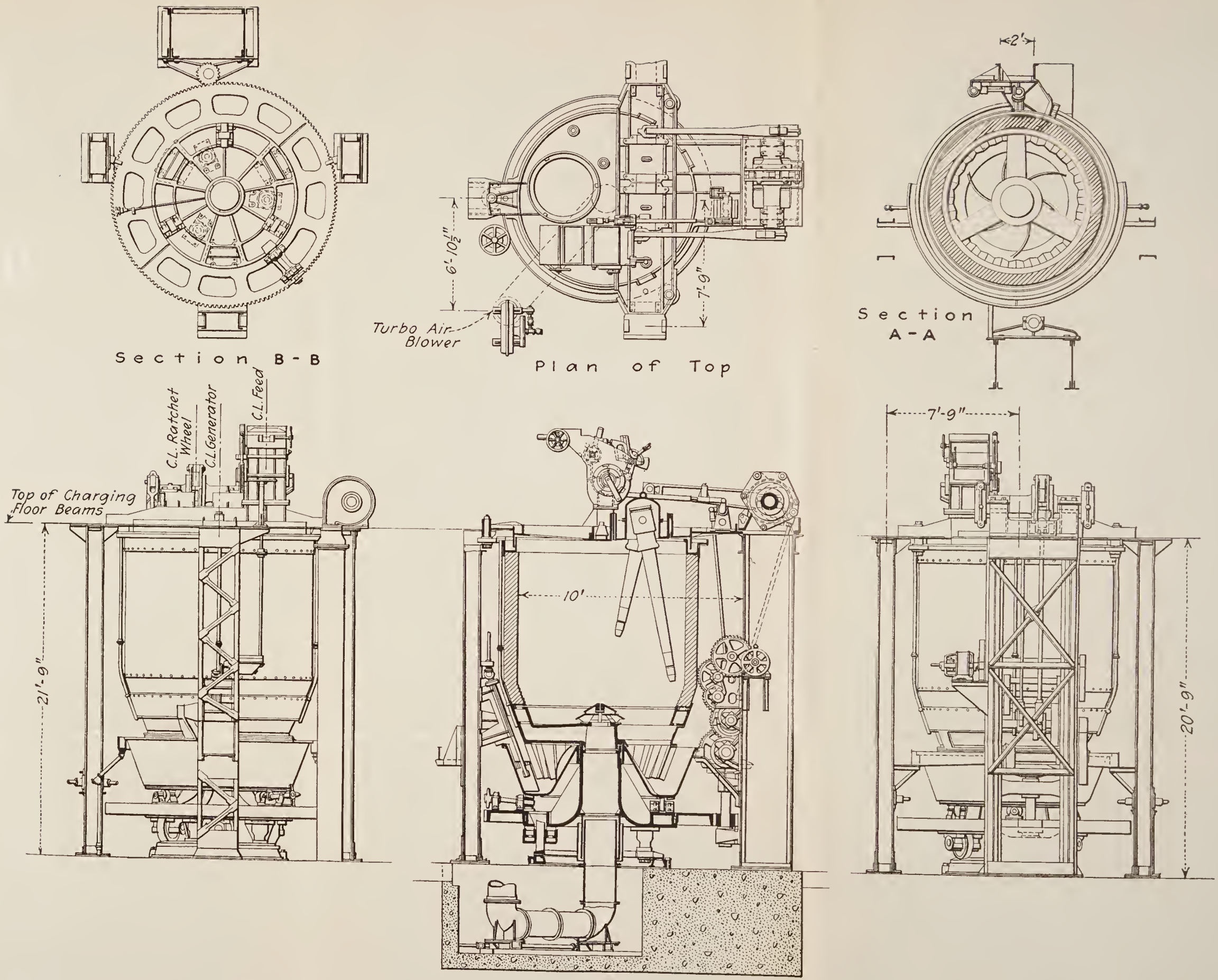

Fig. 31.

By-Product Producer. Deep Fuel Bed. Double Poker

To face page 266.

feres with the washing effect and these sprays will drive this accumulation of dust down to the bottom of the decanter.

Washer Cooler—The gas has now been freed from excessive heat, dust and a large portion of the soot. Very little pitch has been removed and this, together with light and heavy tar and finely divided free carbon and dust, is still present. To remove a portion of these impurities and to prepare the gas for further

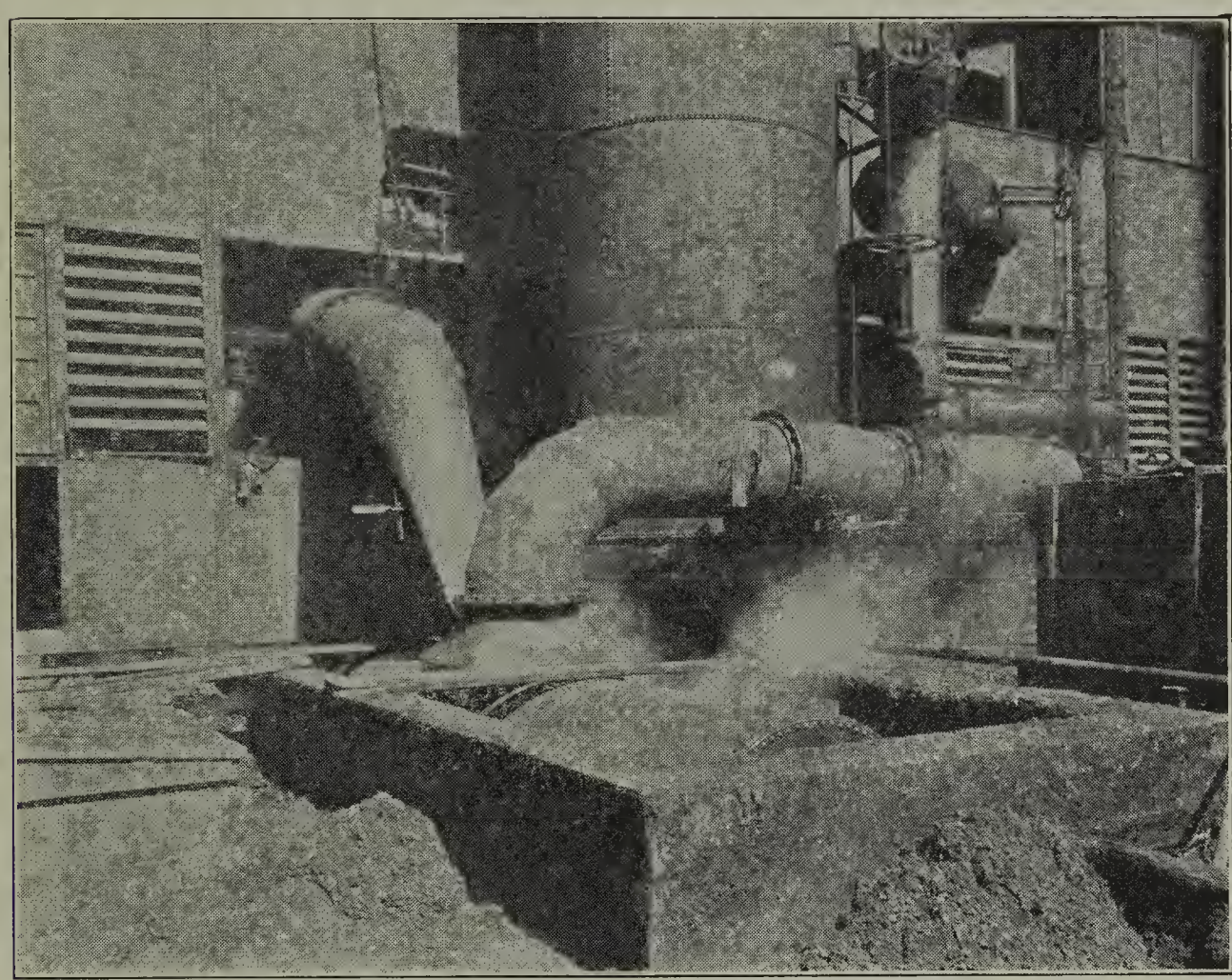

FIG. 32.—Barbotage and Washer Cooler.

treatment, the gas passes through a washer cooler, which is an upright steel shell filled with wooden grids, the gas passing up through the grids, which are heavily sprayed with cold water. (Figure 33.) This is an exceedingly efficient method of cooling gas and also of removing impurities. The gas leaves the washer cooler at a temperature of about 105°. The water enters at about 95° and is brought to a high temperature in passing through the washer cooler, which discharges into the general decanter which extends beneath all the cleaning apparatus.

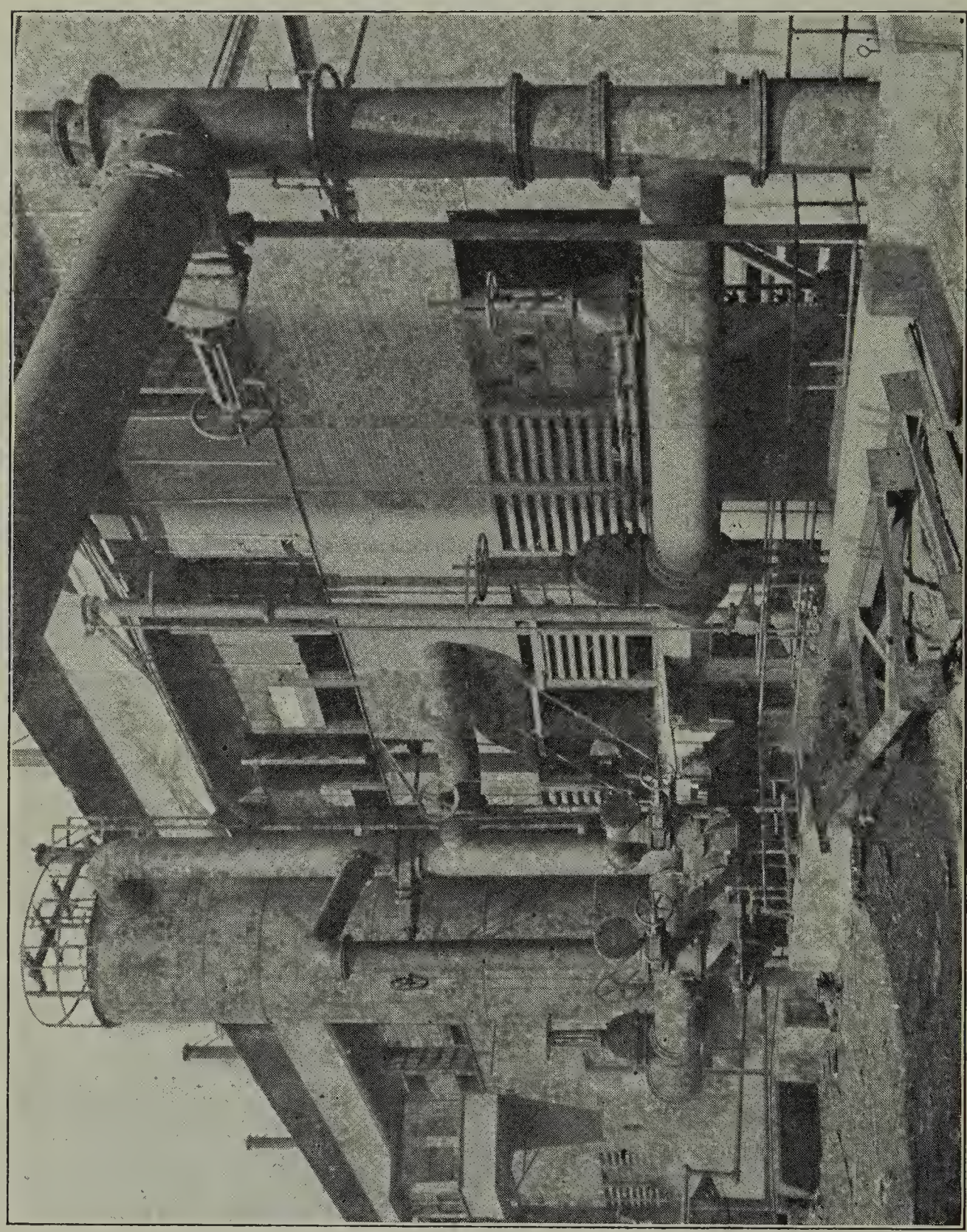

FIG. 33.—Washer Cooler, Tar Beater, Separator and Decanter.

Tar Beater and Ionizer—For the removal of finely divided pitch globules, heavy and light tars and very fine dust, a combination of centrifugal beating and electrical treatment is used. The gas first enters the tar beater, which is an apparatus something like an enclosed fan, which revolves at 1700 R.P.M. and is supplied with a spray of warm water. The centrifugal action on the gas serves to throw out all the large globules of pitch and heavy tar and the tar and pitch which is not thrown out and washed away by the spray is disintegrated into an extremely fine state. It then passes into the ionizer, which consists of a cylindrical shell containing a series of parallel tubes, each tube having at approximately its center a wire carrying electrical charge of alternating current with a potential of about 17,000 volts. Passing through this electrically charged atmosphere, the finely divided globules of tar and pitch are coagulated and coalesced and driven against the walls of the tubes running down into the bottom of the apparatus and going thence to the decanter. The jacket temperature of the ionizer is maintained at about 140° F., which serves to keep the tar and pitch reasonably fluid, so that it will not build up on the tubes. The temperature of the gas passing through the ionizer is maintained at about 100° F. (Figure 34.) After leaving the ionizer, the gas goes to two exhausters built by the Connersville Blower Company and driven by vertical steam engines. These exhausters are automatically governed to maintain a very slight pressure just above the fire in the producers and force the gas through the rest of the cleaning apparatus over into the fuel gas holder. The temperature of the gas leaving the exhausters is about 105° F.

Tar Separator—In the natural course of operating the plant, there are times when various portions of the plant must be bypassed for various reasons, which would permit some tar and dust to be present when leaving the exhausters. To take care of such emergency conditions or overloads, a tar separator was installed, which consists of a rectangular steel box, containing three sets of slotted plates with a backing plate behind each slot. The gas in passing through these knife edge slots is drawn into an exceedingly thin ribbon with high velocity, which, striking against the backing plate, is sharply deflected. This drawing action, combined with the sudden change of direction and further assisted by a spray of cold water which passes down the length of the slot, serves to remove traces of impurities which may be present at this point. After

leaving the tar separator, the gas passes through a vertical pipe, where it rises for several feet, meeting a heavy spray of cold water and thence passes directly to the fuel gas holder, which serves as a relief valve during the periods of reversal of the gas from one side of the coke oven to the other. All the seals on the

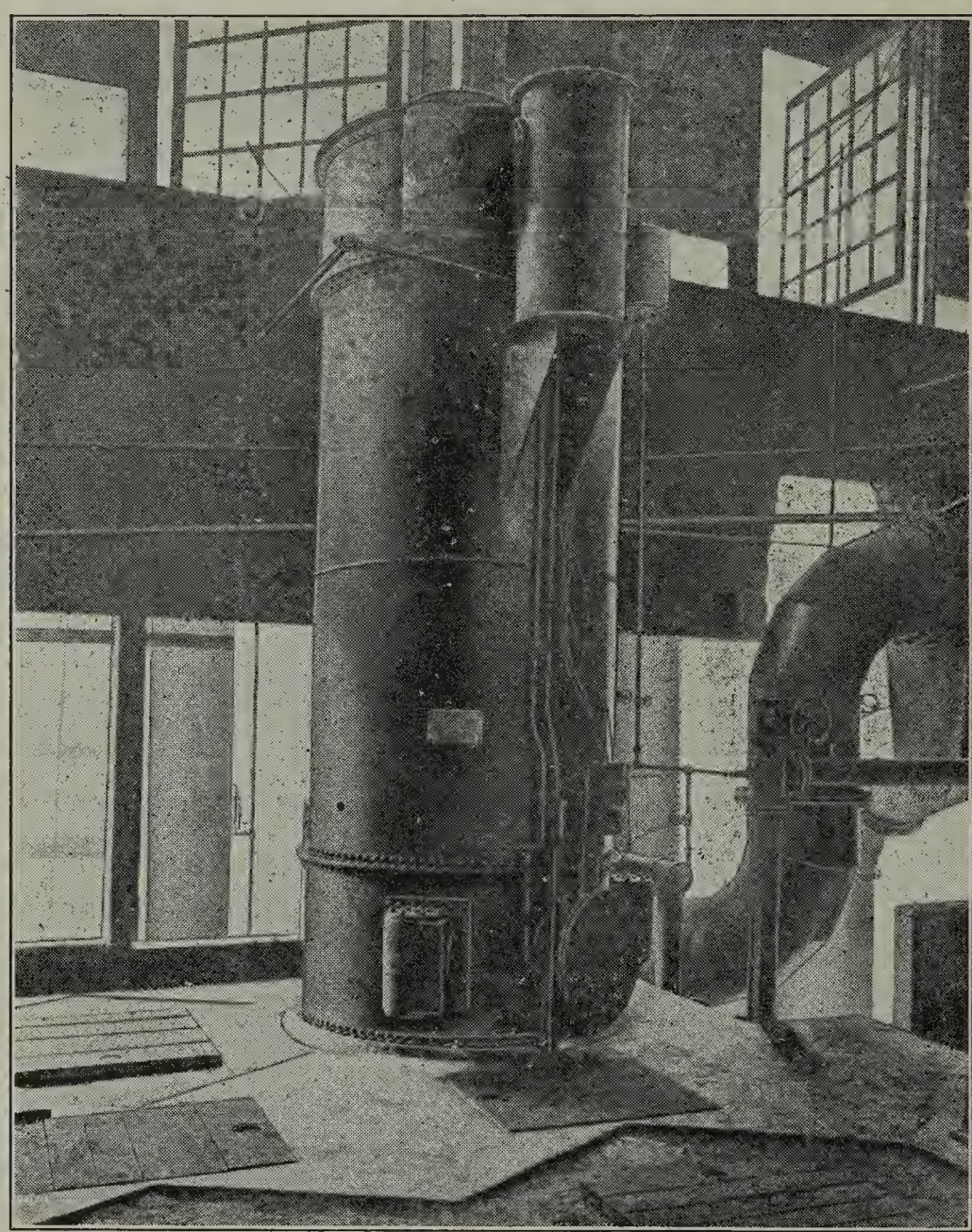

Fig. 34.—Ionizer.

cleaning apparatus discharge into a concrete decanter, which has several different compartments. In this decanter the tar and pitch separate from the water and suitable means are provided for the disposal of these materials.

A set of centrifugal pumps is provided for handling the various circulations of hot, cold and warm water utilized. A suction pipe at the extreme end of the decanter takes the hot water to a

pump, which sprays it in a cooling pond, where it is sufficiently cooled for re-use. The cold water from the cooling pond is drawn back and pumped over the washer cooler, tar separator and other places where a spray of cold water may be necessary. Hot water is secured by a suction line placed directly beneath the washer cooler, and hot water is used on the dust catcher, collection main and barbotage or other places where it may be temporarily desired.

The final results of this plant have not yet been definitely determined, but it has already demonstrated its ability to make absolutely clean gas within certain definite ranges, although the exact capacity of the plant as a whole has not been entirely demonstrated.

Wherever possible use has been made of various instruments for controlling the operation of the plant, such as air and steam meters, pyrometers, pressure gauges and recording and indicating thermometers.

NOTE.—The ionizer was found to be unsuccessful in dealing with the gas from these producers as the tar was of pitchy character and collected on the tubes and wires short circuiting them and vitiating the action. Other means were used for tar removal for a time and later coke was used for fuel instead of coal, which produced very little if any tar.

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